DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
Washington, D.C. 20314-1000

EM 385-1-80

CESO

Manual
No. 385-1-80

30 May 1997

Safety
RADIATION PROTECTION MANUAL

1. Purpose. This guidance manual prescribes the requirements of the Radiation Protection Program of the US Army Corps of Engineers (USACE) contained in Engineer Regulation (ER) 385-1-80, Radiation Protection, and Engineer Manual (EM) 385-1-1, Safety and Health Requirements Manual. It is to be used when activities utilize or handle radioactive material (which includes radioactive wastes) or a radiation generating device.

2. Applicability. This manual is applicable to USACE personnel, and visitors to a worksite under the jurisdiction of USACE where radioactive material or a radiation generating device may be present. It shall be used in conjunction with ER 385-1-80 and EM 385-1-1.

3. References. See Appendix A.

4. Scope. This manual fully describes policies and procedures for the use of radioactive material and radiation generating devices at all USACE sites. It should be used to evaluate the acceptability of practices by USACE personnel and contractors on USACE controlled sites.

FOR THE COMMANDER:

Otis Williams

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Chief of Staff

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Table of Contents

Chapter 1. Organization of USACE Radiation Protection Program.

1-1. Purpose.

This guidance manual prescribes the requirements of the Radiation Protection Program of the US Army Corps of Engineers (USACE) contained in Engineer Regulation (ER) 385-1-80, Ionizing Radiation Protection, and Engineer Manual (EM)385-1-1, Safety and Health Requirements Manual. It is to be used when activities utilize or handle radioactive material (which includes radioactive wastes) or a radiation generating device. Radiation generating devices include X-ray equipment, accelerators, lasers, radio-frequency and electromagnetic field generators. Authoritative guidance and regulations are contained in 10 CFR (Energy) and the NRC Regulatory Guides, 29 CFR (Labor) 1910 and 1926 OSHA regulations, and 40 CFR (Protection of the Environment). This manual is intended to assist USACE Commands in integrating essential requirements contained in Federal, DA and USACE radiation protection regulations to ensure that the safety and health requirements of all agencies are met.

1-2. Applicability.

This manual is applicable to USACE personnel and visitors to a worksite under the jurisdiction of USACE where radioactive material or a radiation generating device may be present. It shall be used in conjunction with ER 385-1-80 and EM 385-1-1. Contractor requirements concerning ionizing and non-ionizing radiation protection issues are contained in EM 385-1-1.

1-3. Policy.

a. USACE will work to ensure that all personnel radiation exposure is kept as low as is reasonably achievable (ALARA) taking technological and socioeconomic factors into account. Radiation exposure to USACE personnel, visitors and contractors, as well as to the general public, will be controlled so that exposures are held well below regulatory limits. There shall be no radiation exposure without a commensurate benefit.

b. All personnel involved with ionizing radiation work of any kind will be knowledgeable of the programs, policies, and procedures contained in ER 385-1-80 and this manual. Personnel working with non-ionizing radiation should be knowledgeable of the specific information concerning these topics presented in this manual. They should demonstrate responsibility and accountability through an informed, disciplined, and cautious attitude toward radiation and radioactivity.

c. Continuing improvement in radiation (ionizing and non-ionizing) protection is essential to USACE operations involving radiation. All personnel working with radiation are expected to look for ways to improve radiation protection and make USACE projects more efficient.

1-4. Management Commitment, Involvement, and Leadership.

Superior, consistent performance is achieved when qualified personnel use approved procedures and when management actively monitors the work place and assesses ongoing activities. To achieve such performance requires constant review, informed involvement and leadership by senior management. All levels of management must emphasize the need for high standards of radiation safety through direct communication, clear instruction, and frequent inspections of the work area.

1-5. Scope.

a. This manual fully describes policies and procedures for the safe use of radioactive material and radiation generating devices at all USACE sites. It should be used to evaluate the acceptability of health and safety practices by USACE personnel and contractors on USACE controlled sites.

b. The manual is also intended to be consistent with all Federal (NRC, OSHA, EPA, DOE, and DOT) DA, USACE, State, and local statutes and regulations (that is, “applicable regulations”), and integrate the various regulations into one coherent publication for USACE operations. It will be revised whenever necessary to achieve consistency with statutes and regulations.

c. For all contracts and activities that require Federal, State, or local licensure or permitting, such licenses or permits shall be secured, and all license or permit conditions shall be adhered to. If the stated license or permit conditions vary from applicable sections of this manual, such license or permit conditions prevail. Contractors will be required to secure proper licensure or permitting (for activities that require it) within specified time frames and before the date that they are scheduled to begin the work. All USACE Commands and contractors using Army radioactive materials will meet requirements of

Nuclear Regulatory Commission (NRC) licenses and Army Radiation Authorizations (ARAs) issued to USACE and the US Army Materiel Command, and of applicable Army technical publications.

e. Alternatives to procedures addressed in this manual may be acceptable provided the alternatives achieve the same, or higher, level of radiation protection. Alternative procedures must be approved by the Radiation Protection Officer, or Laser Safety Officer, as appropriate, and for specific conditions, higher level authorities prior to implementation.

1-6. Overview of this Manual.

This manual is designed to address all health and safety aspects of work with radiation within USACE. Most personnel within USACE will not need the entire manual but will need to select the chapters and sections applicable to their work requirements. Some generic classifications of radiation work are listed in Table 1-1 with reference to the applicable chapters of this manual. It is recommended that all personnel working with radioactive material and radiation generating devices read Chapters 1, 2 and 3 of this manual. Depending on the type of work being performed, portions of other chapters may be applicable.

Table 1-1
Personnel Positions in Relation to Applicable Chapters

Applicable Sections of EM 385-1-80	Personnel Positions				
	AUA	AU	RPO	LSO	SUPERVISOR ORIGINATOR REVIEWER CQA	SOHO RPC RPSO HPs
Chapter 1 - Radiation Protection Program	X	X	X	X	X	X
Chapter 2 - Personnel Responsibilities	X	X	X	X	X	X
Chapter 3 - Introduction to Ionizing Radiation	X	X	X		X	X
Chapter 4 - Licensing		X	X		X	X
Chapter 5 - Dose Limits and ALARA	X	X	X		X	X
Chapter 6 - Working With Radiation	X	X	X		X	X
Chapter 7 - Personnel Monitoring			X		X	X
Chapter 8 - Transportation of Radioactive Material			X		X	X
Chapter 9 - Waste Management			X		X	X
Chapter 10 - Lasers				X	X	X
Chapter 11 - RF & EMF			X		X	X

AUA Authorized User's Assistant AU Authorized User
RPO Radiation Protection Officer LSO Laser Safety Officer
SUPERVISOR Supervisor of activities involving radioactive material
ORIGINATOR Originator of projects/plans/procedures using radioactive material
REVIEWER Reviewer of projects/plans/procedures using radioactive material
CQA USACE Construction Quality Assurance personnel
SOHO Safety and Occupational Health Office
RPC Radiation Protection Committee
RPSO Radiation Protection Staff Officer
HPs Health Physics personnel

Chapter 2. USACE Personnel Responsibilities and Qualifications.

2-1. The Chief, Safety and Occupational Health Office (CESO), HQUSACE.

The Chief, Safety and Occupational Health Office, HQUSACE, is responsible for program management and oversight for licensing, accountability, possession, use, storage, transfer and disposal of all radioactive material and radiation generating devices within USACE. This responsibility shall be discharged by:

a. Appointing and maintaining on staff a qualified Radiation Protection Staff Officer (RPSO).

b. Assuring Command implementation of Department of Army and USACE radiation protection policy.

2-2. Radiation Protection Staff Officer (RPSO).

a. The RPSO is an individual designated by the Chief, Safety and Occupational Health Office, to serve as the MACOM RPSO responsible for the USACE Radiation Protection Program. The RPSO will have the following necessary training, experience, and education:

(1) an individual who meets the qualification and classification standards for the Office of Personnel Management (OPM) job series for a GS-1306, Health Physicist; GS-690, Industrial Hygienist; or GS-803, Safety Engineer; with three years of experience in the occupational health/radiation protection field.

(2) forty hours of formal training covering:

(a) the physics of radiation, radiation's interaction with matter, and the mathematics necessary to understand the above subjects;

(b) the biological effects of radiation;

(c) the instrumentation necessary to detect, monitor, and survey radiation, and the use of such instrumentation; and

(d) radiation safety techniques and procedures. This training shall include the use of time, distance, shielding, engineering controls, and personnel protective equipment (PPE) to reduce exposure to radiation.

(3) practical, hands-on experience using radiation instrumentation, procedures, and theory.

(4) a working knowledge of the Army Radiation Protection Program and the USACE Radiation Protection Program and the record keeping requirements for work with radioactive material and radiation generating devices.

(5) a working knowledge of US Nuclear Regulatory Commission (NRC), US Environmental Protection Agency (EPA), US Department of Energy (DOE), US Department of Transportation (DOT), and US Department of Labor (DOL) which is the responsible for the US Occupational Safety and Health Administration (OSHA), and US Army regulations pertaining to radioactive material and radiation generating devices.

b. Duties of the RPSO are as follows:

(1) Serve as the primary liaison between USACE, DA and NRC in matters concerning radioactive materials or radiation generating devices.

(2) All NRC license actions will be submitted through, reviewed, and accepted by the RPSO.

(3) Provide a copy of all correspondence relating to NRC applications to DA as required. The RPSO will retain copies of all NRC radioactive material licenses and correspondence (originals will be retained by the licensee).

(4) Ensure that each USACE Command possessing an NRC radioactive material license is audited at least triennially to ensure compliance with the USACE Radiation Protection Program. The RPSO, or designee, will check for compliance with the USACE Radiation Protection Program and the NRC radioactive material license. The RPSO, or his designee will document all inspection findings and submit them to the audited USACE Command for review and action.

2-3. USACE Commanders.

USACE Commanders shall:

a. Ensure a Radiation Protection Committee (RPC) shall be formed when the Command possesses an NRC license with a condition stating that the licensee shall have a RPC, or if the Commander considers an RPC necessary. The RPC will consist of personnel and duties described in subparagraph 2-11.

b. Designate, in writing, a qualified person to serve as USACE Radiation Protection Officer (RPO) when any of the following is true:

(1) an NRC License, Army Reactor Permit, ARA or applicable technical publication requires it,

USACE Radiation Protection Program and the record keeping requirements for work with radioactive material and radiation generating devices.

(5) a working knowledge of US Nuclear Regulatory Commission (NRC), US Environmental Protection Agency (EPA), US Department of Energy (DOE), US Department of Transportation (DOT), and US Department of Labor (DOL) which is the responsible for the US Occupational Safety and Health Administration (OSHA), and US Army regulations pertaining to radioactive material and radiation generating devices.

b. Duties of the RPSO are as follows:

(1) Serve as the primary liaison between USACE, DA and NRC in matters concerning radioactive materials or radiation generating devices.

(2) All NRC license actions will be submitted through, reviewed, and accepted by the RPSO.

(3) Provide a copy of all correspondence relating to NRC applications to DA as required. The RPSO will retain copies of all NRC radioactive material licenses and correspondence (originals will be retained by the licensee).

(4) Ensure that each USACE Command possessing an NRC radioactive material license is audited at least triennially to ensure compliance with the USACE Radiation Protection Program. The RPSO, or designee, will check for compliance with the USACE Radiation Protection Program and the NRC radioactive material license. The RPSO, or his designee will document all inspection findings and submit them to the audited USACE Command for review and action.

2-3. <u>USACE Commanders.</u>

USACE Commanders shall:

a. Ensure a Radiation Protection Committee (RPC) shall be formed when the Command possesses an NRC license with a condition stating that the licensee shall have a RPC, or if the Commander considers an RPC necessary. The RPC will consist of personnel and duties described in subparagraph 2-11.

b. Designate, in writing, a qualified person to serve as USACE Radiation Protection Officer (RPO) when any of the following is true:

(1) an NRC License, Army Reactor Permit, ARA or applicable technical publication requires it,

(2) personnel are required to wear dosimetry,

(3) personnel are required to participate in a bioassay program.

c. Fund, maintain and support the RPO and the Radiation Protection Program. The RPO shall meet the qualifications and provide the services described in paragraph 2-4.

d. Fund, maintain and support the Laser Safety Officer (LSO) and the Laser Safety Program when a USACE Command operates, maintains or services a non-type-classified class IIIb or class IV laser system as defined in section 1.3, ANSI Z136.1. The RPO may be designated as the LSO. The LSO shall meet the qualifications and provide the services described in paragraph 2-5.

2-4. Radiation Protection Officer (RPO).

a. The RPO (also known as a Radiation Safety Officer (RSO) in other documents) is a person, designated by the USACE Command, and tasked with the supervision of the USACE Radiation Protection Program for that command. The RPO shall have direct access to the Commander for radiation protection purposes. The RPO ensures compliance with current directives (AR's, ER 385-1-80, EM 385-1-1, etc.) for radiation protection and with this manual. The RPO may limit or cease operations within their Command where there is an eminent and legitimate radiation safety issue.

b. The RPO shall be responsible for:

(1) Establishing written policies and procedures to assure compliance with applicable Federal, DOD, and Army radiation protection regulations and directives. These documents will include emergency reaction plans as necessary and procedures for investigating and reporting radiation accidents, incidents, and overexposures.

(2) Assuring that all personnel occupationally exposed to radiation receive appropriate radiation protection training commensurate with potential hazards from radiation sources they may encounter.

(3) Maintaining an inventory of radiation sources as higher headquarters directs and IAW with requirements of NRC licenses, Army reactor permits, ARAs, and technical publications.

(4) Approving and filing records noting all Authorized Users, Authorized Users' Assistants and site supervisors working with radioactive materials or radiation

generating devices within the Command.

(6) Providing or securing an acceptable source for all required initial and annual refresher training for all individuals within the Command.

c. The RPO will review the USACE Radiation Protection Program for their Command annually for content and implementation. The RPO will assure that the quality and timeliness of the program meet the radiation safety standards outlined in this manual. The RPO will review work with radiation within the Command. The RPO will write and/or review Standing Operating Procedures to ensure the safety, timeliness, and compatibility with existing radiation regulations.

d. The RPO will be technically qualified, meeting the experience, training, and education requirements listed below:

(1) A working knowledge of NRC, EPA, DOE, DOT, and US Army regulations pertaining to radioactive material, radiation generating devices, radioactive and mixed waste used within their Command.

(2) Forty hours of formal training covering:

(a) the physics of radiation, radiation's interaction with matter, and the mathematics necessary to understand the above subjects;

(b) the biological effects of radiation;

(c) the instrumentation necessary to detect, monitor, and survey radiation, and the use of such instrumentation; and

(d) radiation safety techniques and procedures. This training will include the use of time, distance, shielding, engineering controls, and PPE to reduce exposure to radiation.

(3) Practical, hands-on experience using radiation instrumentation, procedures, and theory.

(4) A working knowledge of the Army Radiation Protection Program and the USACE Radiation Protection Program, and the record keeping requirements for work with radioactive material and radiation generating devices used within their Command.

2-5. <u>Laser Safety Officer (LSO).</u>

a. The LSO is a person designated by the USACE Command tasked with the supervision of the Laser Sections of the USACE Radiation Protection Program

for that command. The LSO ensures compliance with current directives for laser safety (EM 385-1-1, TB MED 524, ANSI Z136.1, etc.) and with this manual.

b. The LSO will review the USACE Laser Safety Program for their Command annually for content and implementation. The LSO will assure that the quality and timeliness of the program meet the laser safety standards outlined in this manual. The LSO will write and review Standing Operating Procedures to ensure the safety, timeliness, and compatibility with existing laser regulations.

c. The LSO will be technically qualified, meeting the experience, training, and education requirements listed below:

(1) A working knowledge of applicable regulations pertaining to lasers used within their Command.

(2) Practical, hands-on experience using lasers, laser procedures, and laser theory.

(3) A working knowledge of the Army Radiation Protection Program and the USACE Radiation Protection Program, and the record keeping requirements for work with lasers within their Command.

2-6. Qualified Health Physics Personnel.

A qualified Health Physicist (HP) is responsible for assisting the RPO with their USACE Command Radiation Protection Program, and reviewing Scopes of Work, Work Plans, and/or Site Safety and Health Plans for all work involving radiation. Qualified HPs are personnel:

a. Meeting the Office of Personnel Management Standards for the HP Series, GS-1306, and having three years experience in work with radiation; or

b. Certified as a Health Physicist by the American Board of Health Physics, or certified by the American Board of Industrial Hygiene (Certified Industrial Hygienist) and one year experience working with radiation; or

c. Identified as being a qualified HP by the Director of Army Radiation Protection, Army Safety Office, or the Army Surgeon General, and having three years experience in work with radiation.

2-7. Authorized Users (AUs).

AUs are individuals who, by their training and experience, are allowed to work, unsupervised, with radioactive material or radiation generating devices. AUs may also directly supervise Authorized Users Assistants working with radioactive material. All AUs must be approved by the facility RPC, if one exists. If the facility does not require an RPC, the AUs must be approved by the RPO. All AUs must meet the following training and experience requirements:

a. A working knowledge of applicable regulations pertaining to radioactive material, radiation generating devices, and radioactive and mixed waste with which they may be working;

b. Unless different requirements are stated in the license, authorization or permit conditions, eight clock hours of formal training covering:

(1) the physics of radiation, radiation's interaction with matter, and the mathematics necessary to understand the above subjects;

(2) the biological effects of radiation;

(3) the instrumentation necessary to detect, monitor, and survey radiation, and the use of such instrumentation; and

(4) radiation safety techniques and procedures. This training will include the use of time, distance, shielding, engineering controls, and PPE to reduce exposure to radiation.

c. Practical, hands-on experience using radiation instrumentation and procedures. The level of training will be commensurate with the hazard presented by the radioactive material or radiation generating device; and

d. A working knowledge of the USACE and his or her USACE Command Radiation Protection Program, and the record keeping requirements for the radioactive material and radiation generating devices used in their work.

e. Instruction in their rights and their responsibilities under the USACE Command NRC license, or Army Radiation Authorization (ARA). This includes:

(1) the employer’s duty to provide safe working conditions;

(2) a report of all radiation exposure to the individual;

(3) the individual's responsibility to adhere to the NRC’s regulations and the Commands's radiation material license, or ARA; and

(4) the individual's

responsibility to report any violation or other occurrence to the RPO.

f. Authorized users of portable gauges will also receive 8 hours training in the safety and use of the gauge from the manufacturer.

2-8. Authorized Users' Assistants (AUAs).

AUAs are individuals allowed to work with radioactive material only under the direct supervision of an AU (that is, in the physical presence of the AU). All AUAs must be nominated by the AU and approved by the RPO. AUAs will have the training and experience described below:

a. A total of at least four hours instruction in the following:

(1) the health effects associated with exposure to the radioactive material or radiation they work with;

(2) ways to minimize exposure;

(3) the purpose and use of protective equipment used in their work; and

(4) the applicable regulations to their work.

b. Practical, hands-on experience using radiation instrumentation and procedures.

c. Instruction in their rights and their responsibilities under the USACE Command NRC license, or ARA. This includes:

(1) the employer's duty to provide safe working conditions;

(2) a report of all radiation exposure to the individual;

(3) the individual's responsibility to adhere to the NRC's regulations and the Command's radioactive material license, or ARA; and

(4) the individual's responsibility to report any violation or other occurrence to the RPO.

2-9. Site Supervisors/ Construction Quality Assurance Personnel.

a. Individuals working as site supervisors or construction quality assurance representatives on projects involving radioactive material or radiation generating devices must be knowledgeable of: the principles of radiation protection; applicable regulations pertaining to radioactive material and radiation generating devices,

and the application of these principles and regulations to worker and public health and safety at project sites.

b. Individuals who supervise work or act as construction quality assurance representatives at sites involving radioactive material or radiation generating devices will have a minimum of eight hours of radiation safety training covering the following:

(1) physics of radiation, radiation's interaction with matter, and the mathematics necessary to understand the above subjects;

(2) biological effects of radiation;

(3) instrumentation necessary to detect, monitor, and survey radiation, and the use of such instrumentation; and

(4) radiation safety techniques and procedures. This training will include the use of time, distance, shielding, engineering controls, and PPE to reduce exposure to radiation.

2-10. Project/Plan/Procedure Originators and Reviewers.

a. Individuals who originate or review projects, plans, or procedures involving radioactive material or radiation generating devices must be knowledgeable of the principles of radiation protection, the applicable regulations pertaining to radioactive material and radiation generating devices, and the application of these principles and regulations to worker and public health and safety.

b. Originators and reviewers of plans, projects or procedures for work at sites using radioactive material or radiation generating devices will have a minimum of eight hours of radiation safety training covering the following:

(1) physics of radiation, radiation's interaction with matter, and the mathematics necessary to understand the above subjects;

(2) biological effects of radiation;

(3) instrumentation necessary to detect, monitor, and survey radiation, and the use of such instrumentation; and

(4) radiation safety techniques and procedures. This training will include the use of time, distance, shielding, engineering controls, and PPE to reduce exposure to radiation.

2-11. Radiation Protection Committee (RPC).

a. Each Command possessing an NRC license or an ARA with a condition stating that the licensee shall have an RPC, or where the Commander deems necessary, shall form an RPC. At a minimum, the RPC will consist of:

(1) The Commanding Officer (CO) or deputy;

(2) The RPO, who will act as recorder for all meetings;

(3) The Chief; Safety and Occupational Health Office; and

(4) A representative Authorized User from each group using radioactive material or radiation generating devices in the Command.

b. The RPC is accountable to its USACE Commander. The CO or his/her deputy chairs the RPC. The RPC will meet at least once each six-month period and at the call of the chair. The RPC will continually evaluate radiological work activities, and make recommendations to the RPO and management. In addition to its responsibilities established in the Army Radiation Protection Program, the RPC responsibilities include:

(1) Annual review of USACE Command personnel exposure

records;

(2) Establishing criteria for determining the appropriate level of review and authorization for work involving radiation exposure; and,

(3) Evaluating health and safety aspects of the construction and design of facilities and systems and planned major modifications or work activities involving radioactive material or radiation generating devices.

c. The RPO will furnish the installation commander and RPSO with copies of the minutes of all RPC meetings, within 30 days of the meeting.

2-12. Hazardous, Toxic and Radioactive Waste (HTRW), Center of Expertise (CX).

a. The HTRW-CX provides technical assistance to USACE headquarters, and design districts as requested on all areas of HTRW and environmental remediation. The CX has a staff that includes Technical Liaison Managers (TLMs), Chemists, Regulatory Specialists, Geotechnical, Process, and Cost Engineers, Risk Assessment, Industrial Hygiene and Health Physics personnel.

b. The HTRW-CX can provide technical assistance to the RPSO as requested, including:

(1) licensing,

(2) inspecting,

(3) product development,

(4) and advice and guidance on radiation safety and protection issues.

c. The HTRW-CX can provide support to other Commands on radiation safety issues, including radon, X-ray fluorescence devices for lead monitoring, etc.

2-13. Refresher Training.

USACE personnel who have completed their initial training, shall receive annual refresher training on the material described for each person in this chapter. The refresher training may be comprised of an update of SOPs, review of dosimetry results, changes in standards or guidance, equipment changes, and any other pertinent radiation safety information that needs review. The length of this training is dependent on the specific material being covered, it does not have to equal the time requirements needed for initial training. Personnel who have completed their initial training and any subsequent refresher training, but currently are not and will not be assigned to work involving radiation, are not required to be up-to-date regarding the refresher training requirement. Personnel whose refresher training has lapsed may not work with radiation until after completion of refresher training. Personnel who have not received refresher training for over two years may be required, at the RPO's discretion, to repeat their initial training.

2-14. Additional Training - Special Applications.

Additional training may be required for work involving special applications (for example, plutonium, fissile uranium, tritium, and accelerator facilities). Personnel working with special applications should consult with the HTRW-CX for additional training requirements.

2-15. All Personnel including Visitors, at a Radiation Site.

a. Regulations require that all individuals who are likely to receive 100 mrem above background in one year shall be kept informed of the presence of radioactive material or radiation in the area and shall be instructed annually in the following:

(1) The health effects associated with exposure to the radioactive material or radiation;

(2) Ways to minimize exposure;

(3) The purpose and use of protective equipment and survey instruments used in the area;

(4) The regulations applicable to the area.

b. The extent of instruction shall be commensurate with the extent of the hazard in the area.

Chapter 3. Introduction to Radiation.

3-1. Atomic Structure.

a. The atom, which has been referred to as the "fundamental building block of matter," is itself composed of three primary particles: the proton, the neutron, and the electron. Protons and neutrons are relatively massive compared to electrons and occupy the dense core of the atom known as the nucleus. Protons are positively charged while neutrons are neutral. The negatively charged electrons are found in a cloud surrounding the nucleus.

b. The number of protons within the nucleus defines the atomic number, designated by the symbol Z. In an electrically neutral atom (that is, one with equal numbers of protons and electrons), Z also indicates the number of electrons within the atom. The number of protons plus neutrons in the nucleus is termed the atomic mass, symbol A.

c. The atomic number of an atom designates its specific elemental identity. For example, an atom with a Z=l is hydrogen, an atom with Z=2 is helium, and Z=3 identifies an atom of lithium. Atoms characterized by a particular atomic number and atomic mass are called nuclides. A specific nuclide is represented by its chemical symbol with the atomic mass in a superscript (for example, ^{3}H, ^{14}C, ^{238}U) or by spelling out the chemical symbol and using a dash to indicate atomic mass (for example, radium-222, uranium-238). Nuclides with the same number of protons (that is, same Z) but different number of neutrons (that is, different A) are called isotopes. Isotopes of a particular element have nearly identical chemical properties, but may have vastly different radiological properties.

3-2. Radioactive Decay.

a. Depending upon the ratio of neutrons to protons within its nucleus, an isotope of a particular element may be stable or unstable. Over time, the nuclei of unstable isotopes spontaneously disintegrate or transform in a process known as radioactive decay or radioactivity. As part of this process, various types of ionizing radiation may be emitted from the nucleus. Nuclides which undergo radioactive decay are called radionuclides. This is a general term as opposed to the term radioisotope which is used to describe an isotopic relationship. For example, ^{3}H, ^{14}C, and ^{125}I are radionuclides. Tritium (^{3}H), on the other hand, is a radioisotope of hydrogen.

b. Many radionuclides such as radium-226, potassium-40, thorium-232 and uranium-238 occur naturally in the environment while others such as phosphorus-32 or sodium-22 are primarily produced in nuclear reactors or particle accelerators. Any material which contains measurable amounts of one or more radionuclides is referred to as a radioactive material. As any handful of soil or plant material will contain some measurable amount of radionuclides, we must distinguish between background radioactive materials and man-made or enhanced concentrations of radioactive materials.

c. Uranium, thorium and their progeny, including radium and radon are Naturally Occurring Radioactive Materials (NORM). Along with an isotope of potassium (K-40) these make up the majority of NORM materials and are found in most all soil and water, and are even found in significant quantities within the human body.

d. Another group of radionuclides are referred to as transuranics. These are merely elements with Z numbers greater than that of uranium (92). All transuranics are radioactive. Transuranics are produced in spent fuel reprocessing facilities and nuclear weapons detonations.

3-3. Activity.

a. The quantity which expresses the degree of radioactivity or radiation producing potential of a given amount of radioactive material is activity. The activity may be considered the rate at which a number of atoms of a material disintegrate, or transform from one isotope to another which is accompanied by the emission of radiation. The most commonly used unit of activity is the curie (Ci) which was originally defined as that amount of any radioactive material which disintegrates at the same rate as one gram of pure radium. That is, 3.7×10^{10} disintegrations per second (dps). A millicurie (mCi) = 3.7×10^{7} dps. A microcurie (μCi) = 3.7×10^{4} dps. A picocurie (pCi) = 3.7×10^{-2} dps.

b. The Systeme Internationale (SI) unit of activity is the becquerel (Bq) which equals 1 dps. Systeme Internationale units, such as meters and grams, are in use throughout the rest of the world. Only the United States still uses units of curies for activity.

c. The activity of a given amount of radioactive material is not directly related to the mass of the material. For example, two one-curie sources containing cesium-137 might have very different masses, depending upon the relative proportion of non-radioactive atoms present in each source. for example, 1 curie of pure cesium-137 would weigh 87 grams, and 50 billion kilograms (100 million tons) of seawater would contain about 1 curie of Cs-137 from fallout.

3-4. Decay Law.

a. The rate at which a quantity of radioactive material decays is proportional to the number of radioactive atoms present. This can be expressed by the equation (Eq.):

$$N=N_o e^{-\text{þ}t} \qquad \text{Eq. 1}$$

Where N equals the number of atoms present at time t, N_o is the initial number of radioactive atoms present at time 0, þ is the decay constant for the radionuclide present, (this can be calculated from the half-life of the material as shown below),and e is the base of the natural logarithms. Table 3-1 indicates half-lives and other characteristics of several common radionuclides.

b. Since activity A is proportional to N, the equation is often expressed as:

$$A = A_o e^{-\text{þ}t} \qquad \text{Eq. 2}$$

Table 3-1. Characteristics of Selected Radionuclides

Radionuclide	Half-life	(Type and max. energy in MeV)
hydrogen-3	12.3 years	þ, 0.0186
carbon-14	5370 years	þ, 0.155
phosphorus-32	14.3 days	þ, 1.71
sulfur-35	87.2 days	þ, 0.167
potassium-40	1.3E09 years	þ, 1.310
iodine-125	59.7 days	þ/X, 0.035
cesium-137	30.2 years	þ/X, 0.51/.662
thorium-232	1.4E10 years	þ/X, 4.081
uranium-238	4.4E09 years	þ/X, 4.147
americium-241	432 years	þ/X, 5.49/.059

þ-alpha particle, þ-beta particle, X-gamma or X-ray

c. Half-life. When half of the radioactive atoms in a given quantity of radioactive material have decayed, the activity is also decreased by half. The time required for the activity of a quantity of a particular radionuclide to decrease to half its original value is called the half-life

($T_{1/2}$) for the radionuclide.

d. It can be shown mathematically that the half-life ($T_{1/2}$) of a particular radionuclide is related to the decay constant (þ) as follows:

$$\frac{\ln 2}{T_{1/2}} \quad \frac{0.693}{T_{1/2}} \qquad \text{Eq. 3}$$

Substituting this value of þ into Equation 2, one gets:

$$A \quad A_o e^{\frac{0.693t}{T_{1/2}}}$$

e. Example 1: You have 5 mCi of phosphorus-32 ($T_{1/2}$ = 14.3 days). How much activity will remain after 10 days?

A = ?

A_o = 5 mCi

t = 10 d

þ = $\frac{.693}{14.3\ d}$

A = $A_o e^{-þt}$

$$A \quad 5 \quad e^{\frac{.693}{14} 10}$$

A = 3.1 mCi

f. An alternative method of determining the activity of a radionuclide remaining after a given time is through the use of the equation:

$$f = (½)^{n} \qquad \text{Eq. 4}$$

where f equals the fraction of the initial activity remaining after time t and n equals the number of half-lives which have elapsed. In Example 1 above,

n = $t/T_{1/2}$

n = 10/14.3

= 0.69

f = $(½)^{0.69}$

= 0.62

A = fA_o

= (0.62)(5)

= 3.10 mCi

Both methods may be used to calculate activities at a prior date, that is "t" in the equations may be negative.

g. The activity of any radionuclide is reduced to less than 1% after 7 half-lives and less than 0.1% after 10 half-lives.

3-5. <u>Types of Ionizing Radiation.</u>

a. Ionizing radiation may be electromagnetic or may consist of high speed subatomic particles of various masses and charges.

(1) Alpha Particles.

Certain radionuclides of high atomic mass (for example,, Ra-226, U-238, Pu-239) decay by the emission of alpha particles. These are tightly bound units of two neutrons and two protons each (a helium nucleus). Emission of an alpha particle results in a decrease of two units of atomic number (Z) and four units of atomic mass (A). Alpha particles are emitted with discrete energies characteristic of the particular transformation from which they originate.

(2) Beta Particles.

A nucleus with a slightly unstable ratio of neutrons to protons may decay by changing a neutron into a proton, or a proton into a neutron through the emission of either a high speed electron or positron called a beta particle. This results in a net change of one unit of atomic number (Z), up one for a beta minus and down one for a beta plus. The beta particles emitted by a specific radionuclide range in energy from near zero to up to a maximum value characteristic of the particular transformation.

(3) Gamma-rays.

(a) A nucleus which has disintegrated is left in an excited state with more energy than it can contain. This excited nucleus may emit one or more photons (that is, particles of electromagnetic radiation) of discrete energies to rid itself of this energy. The emission of these gamma-rays does not alter the number of protons or neutrons in the nucleus but instead has the effect of moving the nucleus from a higher to a lower energy state. Gamma-ray emission frequently follows beta decay, alpha decay, and other nuclear decay processes.

(b) X-rays and gamma-rays are electromagnetic radiation, as is visible light. The frequencies of X- and gamma rays are much higher than that of visible light and so each carries much more energy. Gamma- and X-rays cannot be completely shielded. They can be attenuated by shielding but not stopped completely. A gamma emitting nuclide may yield multiple gamma- and X-rays, each with its own discrete energy. It is possible to identify a gamma emitting nuclide by its spectrum.

(4) X-rays.

X-rays are also part of the electromagnetic spectrum and are indistinguishable from gamma-rays. The only difference is their source (that is, orbital electrons rather than the nucleus). X-rays are emitted with discrete energies by electrons as they shift orbits and lose energy following certain types of nuclear excitement or decay processes.

(5) Bremsstrahlung radiation.

When a charged particle passes near the nucleus of an atom, it deviates from its original path and is slowed down by the coulombic interaction with the nucleus. When this occurs, the charged particle will emit a photon to balance the energy. These photons are called bremsstrahlung radiation. Bremsstrahlung radiation only becomes a significant source of exposure from high energy beta particles. The amount of bremsstrahlung radiation emitted is proportional to the Z number of the nucleus the beta interacted with, and the energy of the beta particle.

(6) Neutrons.

(a) Neutrons are uncharged particles released during fission of heavy atoms (uranium) or released from some non-radioactive material after bombardment by alpha particles (americium-beryllium [Am-Be] sources). Because neutrons are uncharged particles, they travel further in matter. When neutrons are sufficiently slowed down in matter (thermalized) they are absorbed by matter with an accompanying burst of gamma radiation. The nature of production of the neutron determines whether it is emitted in a spectrum (as in fission) or at a discrete energy (as from Am-Be sources).

(b) A single radioactive decay event may generate a large number of radiations as illustrated in Table 3-2, for example:

Table 3-2
I-125 Radiations

RADIATION	ENERGY(keV)	DECAY%
Gamma	35	6.7
Ka X-ray	27.4	114
Kb X-ray	31	25.6
L X-ray	3.9	12
K Conv. Elec.	3.7	80
L Conv. Elec.	31	11.8
M+ Conv. Elec.	35	2.5
K Auger Elec.	23	20
L Auger Elec.	3-4	160

KeV: kiloelectron volt

3-6. <u>Interaction of Radiation With Matter.</u>

a. Excitation/Ionization.

The various types of radiation (for example, alpha particles, beta particles, and gamma-rays) impart their energy to matter primarily through excitation and ionization of orbital electrons. The term "excitation" is used to describe an interaction where electrons acquire energy from a passing charged particle but are not removed completely from their atom. Excited electrons may subsequently emit energy in the form of X-rays during the process of returning to a lower energy state. The term "ionization" refers to the complete removal of an electron from an atom following the transfer of energy from a passing charged particle. Any type of radiation having sufficient energy to cause ionization is referred to as ionizing radiation. In describing the intensity of ionization, the term "specific ionization" is often used. This is defined as the number of ion pairs formed per unit path length for a given type of radiation.

b. Characteristics of Different Types of Ionizing Radiation.

(1) Alpha particles have a high specific ionization and a relatively short range. Alpha particles are massive and carry a double positive charge. This combination allows alpha particles to carry a large amount of energy but to easily transfer that energy and be stopped. In air, alpha particles travel only a few centimeters, while in tissue, only fractions of a millimeter. For example, an alpha particle cannot penetrate the dead cell layer of human skin.

(2) Beta particles have a much lower specific ionization than alpha particles and a considerably longer range. The relatively energetic beta's from P-32 have a range of 6 meters in air or 8 millimeters in tissue. The low-energy beta's from H-3, on the other hand, are stopped by only 6 millimeters of air or 5 micrometers of tissue.

(3) Gamma- and X-rays are referred to as indirectly ionizing radiation since, having no charge, they do not directly apply impulses to orbital electrons as do alpha and beta particles. A gamma-ray or X-ray instead proceeds through matter until it undergoes a chance interaction with a particle. If the particle is an electron, it may receive enough energy to be ionized whereupon it causes further ionization by direct interactions with other electrons. The net result is that indirectly ionizing particles liberate directly ionizing particles deep inside a medium, much deeper than the directly ionizing particles could reach from the outside. Because gamma rays and X-rays

undergo only chance encounters with matter, they do not have a finite range. In other words, a given gamma ray has a definite probability of passing through any medium of any depth.

(4) Neutrons are also indirectly ionizing. When striking massive particles such as the nuclei of atoms, the neutron undergoes elastic scattering losing very little energy to the target nucleus. But when a neutron strikes an hydrogen nuclei (a single proton, about the same mass as a neutron) the energy is shared nearly equally between the neutron and the proton resulting in a loss of about half of the neutron's energy before the interaction. The proton now is a charged, directly ionizing particle moving through matter until all of its energy is transferred to the matter.

3-7. Human Health Effects.

The effects of ionizing radiation described at the level of the human organism can be divided broadly into two categories: stochastic (effects that occur by chance) or deterministic (non-stochastic) effects (characterized by a threshold dose below which effects do not occur).

a. Stochastic Effects. Stochastic effects are those that occur by chance. Stochastic effects caused by ionizing radiation consist primarily of genetic effects and cancer. As the dose to an individual increases, the probability that cancer or a genetic effect will occur also increases. However, at no time, even for high doses, is it certain that cancer or genetic damage will result. Similarly, for stochastic effects, there is no threshold dose below which it is relatively certain that an adverse effect cannot occur. In addition, because stochastic effects can occur in unexposed individuals, one can never be certain that the occurrence of cancer or genetic damage in an exposed individual is due to radiation.

b. Deterministic (Non-Stochastic) Effects.

(1) Unlike stochastic effects, deterministic effects are characterized by a threshold dose below which they do not occur. In addition, the magnitude of the effect is directly proportional to the size of the dose. Furthermore, for deterministic effects, there is a clear causal relationship between radiation exposure and the effect. Examples of deterministic effects include sterility, erythema (skin reddening), and cataract formation. Each of

these effects differs from the other in both its threshold dose and in the time over which this dose must be received to cause the effect (that is acute vs. chronic exposure).

(2) The range of deterministic effects resulting from an acute exposure to radiation is collectively termed "radiation syndrome." This syndrome may be subdivided as follows:

(a) hemopoietic syndrome - characterized by depression or destruction of bone marrow activity with resultant anemia and susceptibility to infection (whole body dose of about 200 rads);

(b) gastrointestinal syndrome - characterized by destruction of the intestinal epithelium with resultant nausea, vomiting, and diarrhea (whole body dose of about 1000 rads); and

(c) central nervous system syndrome - direct damage to nervous system with loss of consciousness within minutes (whole body doses in excess of 2000 rads).

(3) The LD_{50} (that is, dose that would cause death in half of the exposed population) for acute whole body exposure to radiation in humans is about 450 rads.

3-8. Determinants of Dose.

The effect of ionizing radiation upon humans or other organisms is directly dependent upon the size of the dose received and the rate at which the dose is received (for example, 100 mrem in an hour versus 100 mrem in a year). The dose, in turn, is dependent upon a number of factors including the strength of the source, the distance from the source to the affected tissue, and the time over which the tissue is irradiated. The manner in which these factors operate to determine the dose from a given exposure differs significantly for exposures which are "external" (that is, resulting from a radiation source located outside the body) and those which are "internal" (that is, resulting from a radiation source located within the body).

a. External Exposures.

(1) Exposure to sources of radiation located outside the body are of concern primarily for sources emitting gamma-rays, X-rays, or high energy beta particles. External exposures from radioactive sources which emit alpha or beta particles with energies less than 70 keV are not significant since these radiations do not penetrate the dead outer cell layer of the skin.

(2) As with all radiation exposures, the size of the dose resulting from an external exposure is a function of:

(a) the strength of the source;

(b) the distance from the source to the tissue being irradiated; and

(c) the duration of the exposure.

In contrast to the situation for internal exposures, however, these factors can be altered (either intentionally or inadvertently) for a particular external exposure situation, changing the dose received.

(3) The effectiveness of a given dose of external radiation in causing biological damage is dependent upon the portion of the body irradiated. For example, because of differences in the radiosensitivity of constituent tissues, the hand is far less likely to suffer biological damage from a given dose of radiation than are the gonads. Similarly, a given dose to the whole body has a greater potential for causing adverse health effects than does the same dose to only a portion of the body.

b. Internal Exposures.

(1) Exposure to ionizing radiation from sources located within the body are of concern for sources emitting any and all types of ionizing radiation. Of particular concern are internally emitted alpha particles which cause significant damage to tissue when depositing their energy along highly localized paths.

(2) In contrast to the situation for external exposures, the source-to-tissue distance, exposure duration, and source strength cannot be altered for internal radiation sources. Instead, once a quantity of radioactive material is taken up by the body (for example, by inhalation, ingestion, or absorption) an individual is "committed" to the dose which will result from the quantities of the particular radionuclide(s) involved. Some medical treatments are available to increase excretion rates of certain radionuclides in some circumstances and thereby reduce the committed effective dose equivalent.

(3) In general, radionuclides taken up by the body do not distribute equally throughout the body's tissues. Often, a radionuclide concentrates in an organ. For example, I-131 and I-125, both isotopes of iodine, concentrate in the thyroid, radium and plutonium in the bone, and

uranium in the kidney.

(4) The dose committed to a particular organ or portion of the body depends, in part, upon the time over which these areas of the body are irradiated by the radionuclide. This, in turn, is determined by the radionuclide's physical and biological half-lives (that is, the effective half-life). The biological half-life of a radionuclide is defined as the time required for one half of a given amount of radionuclide to be removed from the body by normal biological turnover (in urine, feces, sweat).

3-9. Background Radiation.

a. All individuals are continuously exposed to ionizing radiation from various natural sources. These sources include cosmic radiation and naturally occurring radionuclides within the environment and within the human body. The radiation levels resulting from natural sources are collectively referred to as "natural background". Naturally occurring radioactive material (NORM) can be detected in virtually everything. Natural potassium contains about 0.01% potassium-40, a powerful beta emitter with an associated gamma ray. Uranium, thorium and their associated decay products, which are also radioactive, are common trace elements found in soils throughout the world. Natural background and the associated dose it imparts varies considerably from one location to another in the U.S. and ranges from 5 to 80 microroentgens per hour. It is estimated that the average total effective dose equivalent from natural background in the U.S. is about 250 mrem/person/year. This dose equivalent is composed of about 166 mrem/person/year from radon, 34 mrem/person/year from natural radioactive material within the body, 25 mrem/person/year from cosmic radiation, and 25 mrem/person/year from terrestrial radiation.

b. The primary source of man-made non-occupational exposures is medical irradiation, particularly diagnostic procedures (for example, X-ray and nuclear medicine examinations). Such procedures, on average, contribute an additional 100 mrem/person/year in the U.S. All other sources of man-made, non-occupational exposures such as nuclear weapons fallout, nuclear power plant operations, and the use of radiation sources in industry and universities contribute an average of less than one mrem/person/year in the U.S.

3-10. Radiation Quantities.

a. Exposure (roentgen).

Exposure is a measure of the strength of a radiation field at some point. It is usually defined as the amount of charge (that is, sum of all ions of one sign) produced in a unit mass of air when the interacting photons are completely absorbed in that mass. The most commonly used unit of exposure is the roentgen (R) which is defined as that amount of X or gamma radiation which produces 2.58E-4 coulombs per kilogram (C/kg) of dry air. In cases where exposure is to be expressed as a rate, the unit would be roentgens per hour (R/hr) or more commonly, milliroentgen per hour (mR/hr). A roentgen refers only to the ability of PHOTONS to ionize AIR. Roentgens are very limited in their use. They apply only to photons, only in air, and only with an energy under 3 mega-electron-volts (MeV). Because of their limited use, no new unit in the SI system has been chosen to replace it.

b. Absorbed Dose (rad).

Whereas exposure is defined for air, the absorbed dose is the amount of energy imparted by radiation to a given mass of any material. The most common unit of absorbed dose is the rad (Radiation Absorbed Dose) which is defined as a dose of 0.01 joule per kilogram of the material in question. One common conversion factor is from roentgens (in air) to rads in tissue. An exposure of 1 R typically gives an absorbed dose of 0.97 rad to tissue. Absorbed dose may also be expressed as a rate with units of rad/hr or millirad/hr. The SI unit of absorbed dose is the gray (Gy) which is equal to 1 joule/kg which is equal to 100 rads.

c. Dose Equivalent (rem).

(1) Although the biological effects of radiation are dependent upon the absorbed dose, some types of particles produce greater effects than others for the same amount of energy imparted. For example, for equal absorbed doses, alpha particles may be 20 times as damaging as beta particles. In order to account for these variations when describing human health risk from radiation exposure, the quantity, dose equivalent, is used. This is the absorbed dose multiplied by certain "quality" and "modifying" factors (Q) indicative of the relative biological-damage potential of the particular type of radiation. The unit of dose equivalent is the rem (Radiation Equivalent in Man) or, more commonly, millirem. For beta, gamma- or X-ray exposures, the numerical value

of the rem is essentially equal to that of the rad. The SI Unit of dose equivalent is the sievert (Sv) which is equal to: 1 Gy X Q; where Q is the quality factor. Q values are listed in Table 3-3 (Note that there is quite a bit of discrepancy between different agency's values).

Table 3-3
Q Values

Radiation Type	NRC	ICRU	NCRP
X & Gamma Rays	1	1	1
Beta Particles (Except ^{3}H)	1	1	1
Tritium Betas	1	2	1
Thermal Neutrons	2	-	5
Fast Neutrons	10	25	20
Alpha particles	20	25	20

(2) Example: An individual working at a Corps lab with I-125 measures the exposure at a work station as 2 mR/hr. The NRC licenses and regulates the lab. What is the dose equivalent to a person sitting at the work station for six hours?

DE = Exposure x 0.97 rad/R x Q

Exposure = Exposure Rate x Time

Q for gamma-radiation = 1

DE = Rate x Time x 0.97 x Q

DE = 2 mR/hr x 6 hr X 0.97 rad/R x 1 = 11.64 mrem.

d. Deep Dose Equivalent (DDE).

(1) The DDE is the dose to the whole body tissue at 1 centimeter (cm) beneath the skin surface from external radiation. The DDE can be considered to be the contribution to the total effective dose equivalent (TEDE) from external radiation.

(2) Example: A worker is exposed to 2 R of penetrating gamma radiation. What is his/her DDE?

DDE = exposure x 0.97 rad/R x Q
Q for gamma radiation = 1
DDE = 2 R x 0.97 rad/R x 1 = 1.94 rem.

e. Effective Dose Equivalent (EDE).

(1) Multiplying the dose equivalent by a weighting factor that relates to the radiosensitivity of each organ and summing these weighted dose equivalents produces the effective dose equivalent. Weighting Factors are shown in Table 3-4. The EDE is used in dosimetry to account for different organs having different sensitivities to radiation.

Table 3-4
Weighting Factors

Gonads	0.25
Breast	0.15
Lung	0.12
Thyroid	0.03

Bone	0.03
Marrow	0.12
Remainder	0.30

(2) Example: A person is exposed to 3 mR/hr of gamma-radiation to the whole body for six hours. What is the effective dose equivalent to each organ and to the whole body?

EDE = þ (DE x WF)
DE = R x Q
R = Rate x Time
Q for gamma = 1
R = 3 mR/hr x 6 hrs. = 18 mR
18 mR x 0.97 mrad/mR = 17 mrad
DE = 17 mrad x 1 = 17 mrem
EDE for:
Gonads = 17 mrem x 0.25 = 4.25 mrem
Breast = 17 mrem x 0.15 = 2.55 mrem
Lung = 17 mrem x 0.12 = 2.04 mrem
Thyroid = 17 mrem x 0.03 = 0.51 mrem
Bone = 17 mrem x 0.03 = 0.51 mrem
Marrow = 17 mrem x 0.12 = 2.04 mrem
Remainder = 17 mrem x 0.30 = 5.10 mrem

EDE for whole body: 17 mrem.
(note that the weighting factor for the whole body is one)

f. Committed Dose Equivalent (CDE).

(1) The CDE is the dose equivalent to organs from the intake of a radionuclide over the 50-year period following the intake. Radioactive material inside the body will act according to its chemical form and be deposited in the body, emitting radiation over the entire time they are in the body. For purposes of dose recording, the entire dose equivalent organs will receive over the 50-years following the intake of the radionuclides is assigned to the individual during the year that the radionuclide intake took place. The CDE is usually derived from a table or computer program, as the value is dependent upon the radionuclide, its chemical form, the distribution of that chemical within the body, the mass of the organs and the biological clearance time for the chemical. Two common databases are MIRD and DOSEFACT that contain CDEs for various radionuclides. The CDE can be calculated from the data in 10 CFR 20 Appendix B, or from the EPA Federal Guidance Report #11 if there is only one target organ, otherwise the dose must be calculated from the contribution of the radionuclide in every organ to the organ of interest.

(2) Example: An individual ingests 40 microcuries of I-131. What is the CDE? Because the dose to the thyroid from iodine-131 is 100 times greater than the dose to any other organ we can assume that the

thyroid is the only organ receiving a significant dose and can use the 10 CFR 20 approach, from 10 CFR 20, Appendix B. The non-stochastic (deterministic) Annual Limit of Intake (ALI) is 30 µCi. A non-stochastic ALI is the activity of a radionuclide that, if ingested or inhaled, will give the organ a committed dose equivalent of 50 rem.
DE/ALI x 50 rem = committed dose equivalent to the organ.
40 µCi/30 µCi x 50 rem = <u>67 rem</u>.

(3) An example of the CDE derived from a table is presented in Table 3-5 for inhalation of Co-60.

g. Committed Effective Dose Equivalent (CEDE).

(1) Multiplying the committed dose equivalent by a weighting factor that relates to the radiosensitivity of each organ and summing these weighted dose equivalents produces the committed effective dose equivalent. The CEDE can be considered to be the contribution from internal radionuclides to the TEDE.

(2) Example: A male worker inhales 10 µCi Co-60. What is his CEDE?

Using the CDE above for Co-60, and the weighting factors above, we get the following:
EDE for:

Gonads = 10 µCi x 6.29E+00 mrem/µCi x 0.25 =
15.73 mrem

Table 3-5
Inhalation Coefficients ($H_{50,T}$) in mrem/µCi

Co-60 ($T_{½}$ = 5.271 year) Class Y F1 = 5.0E-02 AMAD = 1.0 µm

organ	($H_{50,T}$)	organ	($H_{50,T}$)
Adrenals	1.11E+02	Lungs	1.27E+03
Bladder Wall	1.09E+01	Ovaries	1.76E+01
Bone surface	4.99E+01	Pancreas	1.17E+02
Breast	6.80E+01	Red Marrow	6.36E+01
Stomach Wall	1.01E+02	Skin	3.77E+01
Small Intestine	2.60E+01	Spleen	9.99E+01
Up lg Intestine	3.59E+01	Testes	6.29E+00
Lw lg intestine	2.93E+01	Thymus	2.12E+02
Kidneys	5.77E+01	Thyroid	5.99E+01
Liver	1.23E+02	Uterus	1.70E+01

$H_{rem,50}$ = 1.33E+02 $H_{E,50}$ = 2.19E+02
ICRP 30 ALI = 30 µCi

Breast= 10 µCi x 6.80E+01 mrem/µCi x 0.15 = 102.00 mrem

Lung = 10 µCi x 1.27E+03 mrem/µCi x 0.12 = 1524.00 mrem

Thyroid= 10 µCi x 5.99E+01 mrem/µCi x 0.03 = 17.97 mrem

Bone = 10 µCi x 4.99E+01 mrem/µCi x 0.03 = 14.97 mrem

Marrow = 10 µCi x 6.36E+01 mrem/µCi x 0.12 = 76.32 mrem

Remainder = 10 µCi x 1.33E+02 mrem/µCi x 0.30 = 399.00 mrem

CEDE for whole body: 2149 mrem

h. Total Effective Dose Equivalent (TEDE).

(1) The sum of the DDE and the CEDE. Dose from internal radiation is no different from dose from external radiation. Regulations are designed to limit TEDE to the whole body to 5 rem per year, and to limit the sum of the DDE and the CDE to any one organ to 50 rem per year.

(2) Example: The person working in example d. also inhales 10 µCi Co-60 as in example g. What is his or her TEDE?

TEDE = DDE + CEDE
From Example d his DDE is 1.74 rem = 1,740.00 mrem
From example g his CEDE is
2,149.00 mrem

TEDE <u>3,889.00 mrem</u>

3-11. <u>Biological Effects of Ionizing Radiation.</u>

Biological effects of radiation have been studied at different levels; the effects on cells, the effects on tissues (groups of cells), the effects on organisms, and the effects on humans. Some of the major points are reviewed below.

a. Cellular Effects.

(1) The energy deposited by ionizing radiation as it interacts with matter may result in the breaking of chemical bonds. If the irradiated matter is living tissue, such chemical changes may result in altered structure or function of constituent cells.

(2) Because the cell is composed mostly of water, less than 20% of the energy deposited by ionizing radiation is absorbed directly by macromolecules (for example, Deoxyribonucleic Acid (DNA). More than 80% of the energy deposited in the cell is absorbed by water molecules where it may form highly reactive free radicals.

(3) These radicals and their products (for example, hydrogen peroxide) may initiate numerous chemical reactions which can result in damage to macromolecules and/or corresponding damage to cells. Damage produced within a cell by the radiation induced formation of free radicals is described as being by indirect action of radiation.

(4) The cell nucleus is the major site of radiation damage leading to cell death. This is due to the importance of the DNA within the nucleus in controlling all cellular function. Damage to the DNA molecule may prevent it from providing the proper template for the production of additional DNA or Ribonucleic Acid (RNA). In general, it has been found that cell radiosensitivity is directly proportional to reproductive capacity and inversely proportional to the degree of cell differentiation. Table 3-6 presents a list of cells which generally follow this principle.

Table 3-6. List of Cells in Order of Decreasing Radiosensitivity

Very radiosensitive	Moderately radiosensitive	Relatively radioresistant
Vegetative intermitotic cells, mature lymphocytes, erythroblasts and spermatogonia, basal cells, endothelial cells.	Blood vessels and interconnective tissue, osteoblasts, granulocytes and osteocytes, sperm erythrocytes.	Fixed postmitotic cells, fibrocytes, chondrocytes, muscle and nerve cells.

(5) The considerable variation in the radiosensitivities of various tissues is due, in part, to the differences in the sensitivities of the cells that compose the tissues. Also important in determining tissue sensitivity are such factors as the state of nourishment of the cells, interactions between various cell types within the tissue, and the ability of the tissue to repair itself.

(6) The relatively high radiosensitivity of tissues consisting of undifferentiated, rapidly dividing cells suggest that, at the level of the human organism, a greater potential exists for damage to the fetus or young child than to an adult for a given dose. This has, in fact, been observed in the form of increased birth defects following irradiation of the fetus and an increased incidence of certain cancers in

individuals who were irradiated as children.

3-12. Ways to Minimize Exposure.

a. There are three factors used to minimize external exposure to radiation; time, distance, and shielding. Projects involving the use of radioactive material or radiation generating devices need to be designed so as to minimize exposure to external radiation, and accomplish the project. A proper balance of ways to minimize exposure and the needs of the project need to be considered from the earliest design stages. For example, if a lead apron protects a worker from the radiation, but slows him or her down so that it requires three times as many hours to complete the job, the exposure is not minimized. Additionally, placing a worker in full protective equipment and subjecting the worker to the accompanying physical stresses to prevent a total exposure of a few millirems does not serve the needs of the project or of the worker.

(1) Time.

Dose is directly proportional to the time a individual is exposed to the radiation. Less time of exposure means less dose. Time spent around a source of radiation can be minimized by good design, planning the operation, performing dry-runs to practice the operation, and contentious work practices.

(2) Distance.

Dose is inversely proportional to the distance from the radiation source. The further away, the less dose received. Dose is related to distance by the equation:

$$I_2 \quad I_1\left(\frac{D_1}{D_2}\right)^2$$

Where:
I_1 = Intensity at Distance 1,
D_1 = Distance 1,
I_2 = Intensity at Distance 2,
D_2 = Distance 2.

Doubling the distance from a source will quarter the dose (see Figure 3-1).

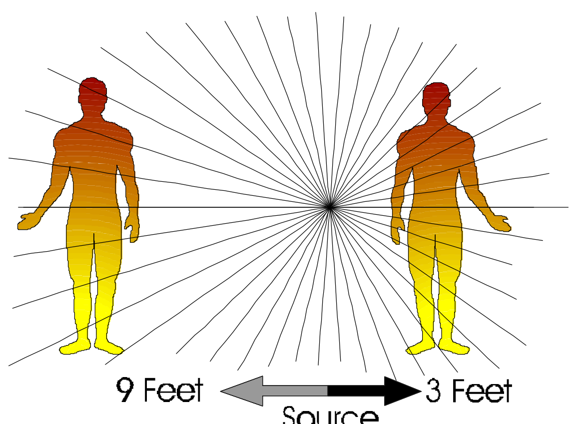


Figure 3-1.

Distance from a radiation source can be maximized by good design, planning the operation, using extended handling tools or remote handling tools as necessary, and by conscienscious work practices.

(3) Shielding

(a) Dose can be reduced by the use of shielding. Virtually any material will shield against radiation but its shielding effectiveness depends on many factors. These factors include material density, material thickness and type, the radiation energy, and the geometry of the radiation being shielded. Consult a qualified expert to determine shielding requirements. Cost considerations often come into play. The shielding provided by a few centimeters of lead may be equaled by the shielding provided by a few inches of concrete, and the price may be lower for the concrete. Table 3-7 lists half-value layers for several materials at different gamma ray energies.

(b) Shielding can be used to reduce dose by placing radiation sources in shields when not in use, placing shielding between the source and yourself, good design of the operation, and contentious work practices.

Table 3-7
Half-value layers (cm) for gamma rays

E_p (MeV)	Lead	Concrete	Water	Iron	Air
0.1	0.4	3.0	7.0	0.3	3622
0.5	0.7	7.0	15.0	1.6	6175
1.0	1.2	8.5	17.0	2.0	8428
1.5	1.3	10.0	18.5	2.2	10389

b. Personnel Protective Equipment (PPE).

PPE is a last resort method for radiation exposure control. When engineering controls using time, distance, shielding, dust suppression, or contamination control cannot adequately lower the exposure to ionizing radiation or radioactive material, PPE may be used. PPE may include such items as:

(1) full-face, air-purifying respirators (APRs) with appropriate cartridges;

(2) self-contained breathing apparatus (SCBA);

(3) supplied air; and

(4) shielded gloves, aprons, and other clothing.

c. Selection of PPE is based on unique conditions at each job site. The PPE may be required in the following circumstances:

(1) when handling contaminated materials with removable contamination;

(2) when working in contamination, high contamination, and Airborne Radioactivity Areas; or

(3) when required by an NRC license or ARA.

d. Specific PPE requirements for each job site should be obtained from USACE or a USACE contractor HP or industrial hygienist. Respirator use must meet the requirements of 29 CFR 1910 or 1926 and USACE respiratory protection requirements of EM 385-1-1. The respiratory protection factors for different types of respirators are listed in 10 CFR 20, Appendix A.

NOTE Half-face APRs will not be used for any USACE work involving radioactive material, unless there is no other practical solution. Any special use of half-face APRs will first be approved by the RPO.

e. Cartridges for radionuclides must be selected with consideration for the radionuclide's chemical form. Respirator filters approved for use under 30 CFR 11 may still be used until July 1998. By that time, all respirator cartridges must be classified according to the new National Institute of Occupational Safety and Health (NIOSH) modular approach described in 42 CFR 84. With the new modular approach to respirator certification, cartridges approved by NIOSH, will no longer be labeled for dusts/mists/fumes/radioactive dusts. The color coding has also changed. Dust/mist/fume filters will now be labeled as N95, N99, N100, R95, R99, R100, P95, P99, and P100. The number relates to the filtering efficiency, and the letter relates to the type of aerosol, with P100 being the most protective over the widest range of aerosol types. Dust/mist and dust/mist/fume cartridges do not provide any protection against radioactive vapors or radioactive noble gases. Consider the use of combination cartridges to control dust and vapors, and activated charcoal cartridges to control noble gasses. When selecting APRs, consider the buildup of radioactive material in the cartridges. A high concentration of gamma radiation-emitting particles or vapor in cartridges may produce a radiation field positioned very close to the face and chest of the person wearing the APR.

f. Any PPE will slow down the working speed of personnel, and extend the time needed for entry and exit. The increase in dose due to the increased time in the radiation field must be weighed against the radiation dose reduction caused by the use of PPE. The use of whole body personal protective equipment, particularly the impermeable type can cause heat stress problems. A heat stress monitoring program shall be implemented to evaluate and control heat stress hazards whenever PPE is used.

3-13. Standing Operating Procedures.

Where a project or operation uses radiation in a method that is amenable to written standing operating procedures (SOPs), the RPO overseeing the operations shall assist in the preparation of SOPs. Most manufacturers of instruments and articles containing radioactive material or that generate ionizing radiation, include SOPs in their operating manuals. The RPO shall review these SOPs and ensure that they meet USACE safety guidelines outlined in this manual and the requirements of ER 385-1-80 and EM 385-1-1 before use.

3-14. Monitoring and Surveying Equipment.

a. Anytime personnel are working with radioactive material or radiation generating devices, radiation monitoring procedures will be used. Equipment needs to be selected that can detect the radiation or radiations in question. Table 3-8 is a general guide to types of detectors and the range and types of radiations they detect. Some radiations are extremely difficult to detect in the field. Weak beta emitters such as tritium (maximum beta energy of 18.6 kilo-electron volts (keV) and weak gamma emitters such as iodine-125 present monitoring problems. Prior to work involving radioactive materials, consult the RPO and HP to select appropriate instruments and procedures for the detection and quantification of the specific radiation in question.

b. Radiation Monitoring Instruments.

(1) Gas-filled Detectors.

Gas-filled detectors consist of a gas-filled chamber with a voltage applied such that a central wire becomes the anode and the chamber wall the cathode. Any ion pairs produced by radiation interacting with the chamber move to the electrodes where they are collected to form an electronic pulse which can be measured and quantified. Depending upon the voltage applied to the chamber, the detector may be considered an ionization chamber, a proportional counter or a Geiger-Muller (GM) detector.

(a) An ionization chamber is a gas-filled chamber containing an anode and a cathode. As radiation passes through the gas it ionizes some of the gas molecules. These ion pairs are attracted to the anode and cathode and create an electrical pulse. The pulses are counted and integrated and displayed on the meter face in roentgens per hour. Because of its design, an ionization chamber has a very linear response to radiations of different energies. For this reason, an ionization chamber is the preferred instrument for quantifying personnel external radiation exposures.

(b) Because of its versatility and dependability, the GM detector is the most widely used portable survey instrument. A GM detector with a thin window can detect alpha, beta and gamma radiation. It is particularly sensitive to medium-to-high energy beta particles (for example, as from P-32) and X-and gamma-rays as well. The GM detector is fairly insensitive to low energy X or gamma rays; that is below 50 keV, to low energy beta particles such as those emitted by S-35 and C-14, and cannot detect the weak betas from H-3 at all. Unlike the ionization chamber, the GM detector does not actually "measure" exposure rate. It instead "detects" the number of particles interacting in its sensitive volume per unit time. The GM should thus read-out in counts per minute (cpm) although it can be calibrated to approximate mR/hr for certain situations. With these advantages and limitations a Geiger-Muller detector on a rugged survey meter is the instrument of choice for initial entry and survey of radiation sources and radioactive contamination in the field.

(2) Scintillation Detectors.

(a) Scintillation detectors are based upon the use of various phosphors (or scintillators) which emit light in proportion to the quantity and energy of the radiation they absorb. The light flashes are converted to photo electrons which are multiplied in a series of diodes (that is, a photomultiplier) to produce a large electrical pulse. Because the light output and resultant electrical pulse from a scintillator is proportional to the amount of energy deposited by the radiation, scintillators are useful in identifying the amount of specific radionuclides present (that is, scintillation spectrometry).

(b) Portable scintillation detectors are widely used for conducting various types of radiation surveys. Of particular use to workers working with low energy gamma radiation, as from radioiodine, is the thin crystal sodium iodide (NaI) detector which is capable of detecting the emissions from I-125 with efficiencies nearing 20% (a GM detector is less than 1% efficient for I-125).

c. Assaying Instruments.

(1) The most common means of quantifying the presence of beta-emitting radionuclides is through the use of liquid scintillation counting. In these systems, the sample and phosphor are combined in a solvent within the counting vial. The vial is then lowered into a well between two photomultiplier tubes for counting.

(2) Solid scintillation detectors are particularly useful in identifying and quantifying gamma-emitting radionuclides. The common gamma well-counter employs a large (for example, 2" x 2" or 3" x 3") crystal of NaI within a lead shielded well. The sample vial is lowered directly into a hollow chamber within the crystal for counting. Such systems are extremely sensitive but do not have the resolution of more recently developed semiconductor counting systems, such as high-purity germanium detectors.

d. Neutron detectors, sometimes called 'neutron balls' or 'rem balls' are used for detection of neutrons. Neutron detectors use a hydrogenous moderator to slow down the neutrons which will allow the neutrons to interact with charged particles. These charged particles then are detected using a conventional radiation detector. Boron trifluoride (BF_3) is a common detector gas used for neutron detection.

e. Semiconductor diode detectors or solid state

Table 3-8
Radiation Detection Instruments

Detector type	Radiation Detected	Detection Limit	Comments
GM-thick walled	þ >50 keV	100 dpm	Limited use.
GM-thin window	ß >35 keV þ >35 keV	100 dpm	Good for detecting contamination, not good for quantifying.

Detector type	Radiation Detected	Detection Limit	Comments
NaI- 2" x 2" crystal	þ >50 keV	500 dpm	Good for detection and quantification.
NaI-thin crystal	ß >50 keV þ >25 keV	500 dpm	Good for detecting low-energy gamma radiation.
Ionization Chamber	ß >50 keV þ >50 keV	0.2 mR/hr	Most accurate for exposure measurement.
Pressurized Ionization Chamber	þ >50 keV	.01 mR/hr	Good for environmental surveys.
Micro R meter	þ >50 keV	.01 mR/hr	Good for environmental surveys.
HPGe	þ >40 keV	variable	Lab equipment, can quantify trace amounts. Field models available.
Liquid Scintillation	þ, ß, þ	variable	Lab equipment, can quantify trace amounts. Field models available.
Gas Proportional	þ, ß, þ	variable	Lab equipment, can quantify trace amounts field models available.

detectors use a solid material with a charge applied to it to detect the energy deposited by radiation. These detectors can be designed to provide good detection of most all radiation, but particular types of radiation and energy ranges, each call for a different configuration.

f. One type of solid state detector that is finding widespread use is the high purity germanium detector (HPGe). The HPGe, like its predecessor the germanium-lithium (GE(Li)) detector, has excellent energy resolution and is commonly used in laboratories for identification and quantification of gamma emitting radionuclides. A primary drawback of the HPGe detector is the requirement to supercool the detector. This is done by attaching a Dewar flask containing liquid nitrogen to the detector. HPGe systems are being made that are field portable, using small Dewar flasks and laptop computers, and can provide laboratory quality analysis in the field.

g. Energy proportional detectors such as scintillation detectors, semiconductor diode detectors and HPGe detectors are often coupled with a multi-channel analyzer (MCA) to allow for determination of the energy of the radiation detected, and through reference, to determine the radioisotope that emitted the radiation and the quantity of that isotope in the sample measured. Most modern MCAs are used in conjunction with computers which process the information, contain the library of radionuclides referenced by energy of radiation, and display software for digital and graphic output.

h. Instrument Calibration.

(1) Radiation survey meters are calibrated with a radioactive source and an electronic pulser. When an electronic calibration is performed, the instrument is checked for response to a radioactive source. In most situations, survey meters must be calibrated at least annually and after servicing. (Battery changes are not considered "servicing".)

(2) Survey meters will be function tested with a check source or other dedicated source before each use. If the survey meter is not responding properly, it may not be used for surveys until it is repaired. There is no need to keep a record of the function checks, but a record must be kept of the discovery of the improper response and the service of the meter to correct the problem, as well as of the recalibration of the meter.

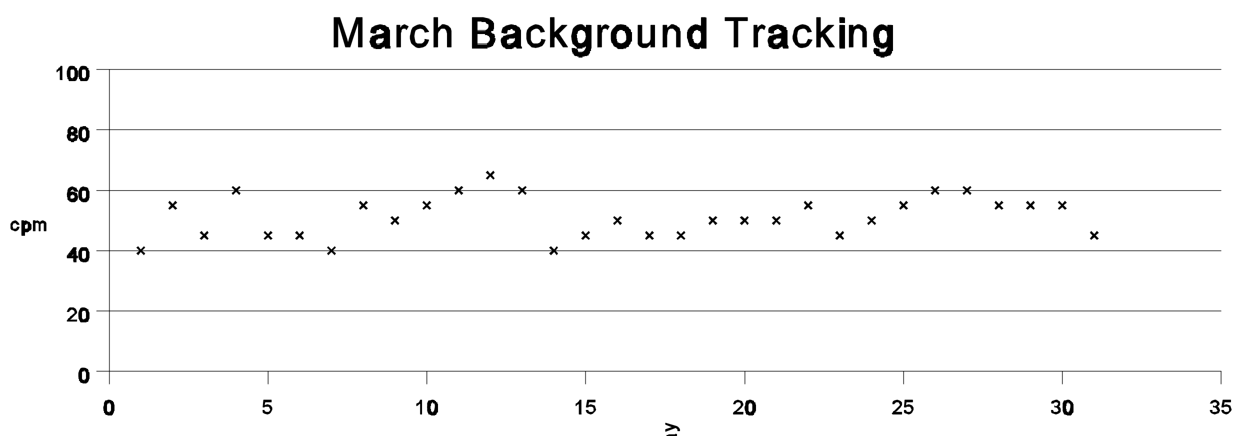
I. Quality Control.

Quality control of instrumentation is essential in a radiation protection program. All instruments used for monitoring safety and health should be subjected to a quality control (QC) program. Two tracking/trending methods are commonly used in instrument QC. The general principle is applicable to both field and lab instruments. The two methods are background trending and check source trending.

(1) Background trending is done by plotting the daily background reading versus days since last calibration. Background trending can indicate when instrument probes become contaminated, by showing a rise in the background rate. Care must be taken in measuring the background daily to assure

that the instrument is in approximately the same location and that the location is contaminant free.

(2) Check-source tracking is a method of assuring that the instrument is responding properly, and remaining in calibration. Check-source tracking is performed by plotting a daily check source reading of a dedicated check source against the days since calibration. Check-source tracking can indicate damage to the instrument or probe, variance of the electronics or changes in the meter response. Figure 3-2 is an example of background tracking and check-source tracking.



x-background count

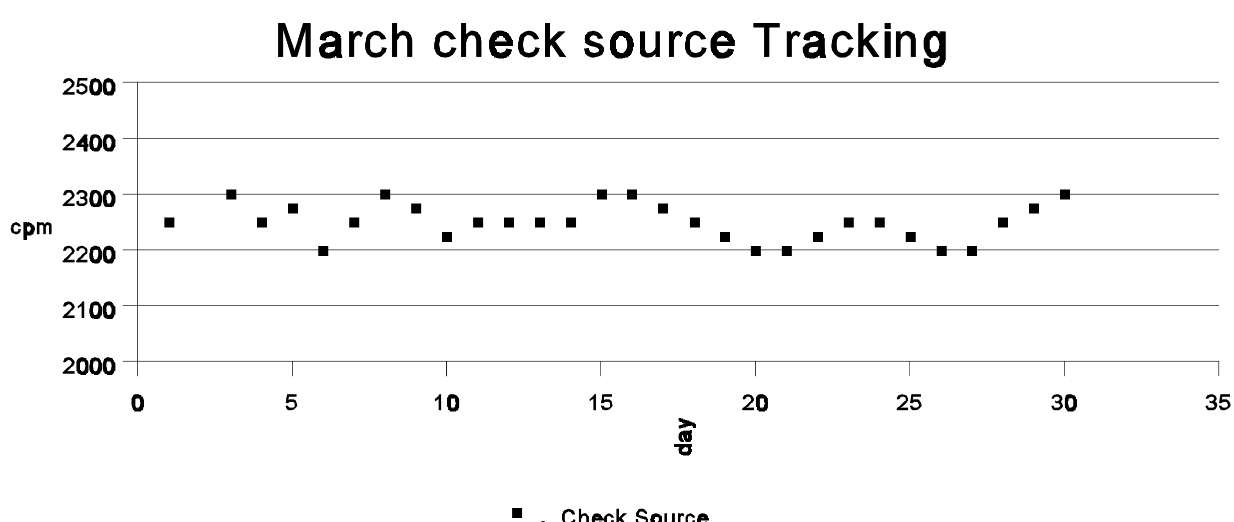


Figure 3-2

Chapter 4. Licensing.

4-1. Overview of Regulatory Agencies.

a. Nuclear Regulatory Commission (NRC).

(1) The Atomic Energy Act of 1954 charges the NRC with the responsibility of writing and enforcing regulations concerning the use of radioactive material. A license is required for possession of source, byproduct or special nuclear material and license holders are inspected by NRC to determine if regulations are being followed by the licensee. If serious or repeated violations occur, a license may be revoked and the radioactive material confiscated. Table 4-1 lists NRC regional offices, NRC Form 3, attached at Appendix H, indicates what NRC region states fall under.

(2) Although the NRC is the federal agency responsible for adopting and enforcing rules and regulations that apply to users of radioactive material, broad administrative responsibilities have been transferred to some state governments. In 1959 the NRC was permitted to make agreements with those states that could operate a suitable radiological health program for the radioactive material users in their states. States that have such agreements with the NRC are called Agreement States. Table 4-2 lists the Agreement States and each state's radiological health program office and emergency phone numbers.

b. Agreement States.

Agreement states have their own state regulations and they provide personnel to license and inspect users of radioactive material. Agreement state regulations must be as stringent as NRC regulations and, usually, are more stringent. The primary difference in most Agreement state regulations is the inclusion of NORM and Naturally occurring and Accelerator produced Radioactive Material (NARM) materials (such as radium, thorium, and cobalt-57) as well as source, byproduct and special nuclear material as regulated materials. The NRC does not regulate NORM or NARM (only source, byproduct, and special nuclear material). Agreement states do not issue licenses to Federal agencies, including the US Army; only the NRC may do so.

c. Environmental Protection Agency (EPA).

The Atomic Energy Act and Reorganization Plan No. 3 authorized the EPA to establish standards to protect human health and the environment from the effects of radiation. The EPA does not license radioactive materials, but regulates their release to the environment and the exposure of the public to radiation.

d. Occupational Safety and Health Administration (OSHA).

OSHA is authorized to protect worker health and safety. OSHA does not license radioactive materials, but regulates their use in the workplace. To protect workers from radiation, OSHA, in 1984, adopted the NRC regulations specified in 10 CFR 20, as it stood in 1984. 10 CFR 20 was amended by the NRC in 1994. Consequently, there are two sets of regulations governing Authorized Users' Assistants with NRC licensable materials; the NRC regulations and OSHA regulations. This is explained more thoroughly in Chapter 5; Dose Limits and ALARA.

4-2. Types of NRC Radioactive Material Licenses. Nuclear Regulatory Commission licenses for radioactive material are of two types: general and specific.

a. General Licenses.

(1) NRC general licenses are provided in 10 CFR 31 and are effective without submitting an application and without receiving a licensing document. Generally licensed devices usually contain little activity and pose minimal risk to the user. Devices which may be generally licensed include: static eliminators, some calibration sources, some measuring, gauging and controlling devices and self-luminous exit signs. Generally licensed material still requires compliance with 10 CFR 19 and 10 CFR 20 requirements for worker instructions and notices, and radiation protection standards. Additionally, for many generally licensed items, there are requirements for semi-annual leak testing and inventories, as well as prohibitions on transfer or disposal except for return to the manufacturer or transfer to the holder of a specific license for that radioactive item.

(2) Example: ABC Co. has a specific license to manufacture and to distribute a gas chromatograph (GC) containing a 50 mCi Ni-63 sealed source to general licensees. A USACE lab (the general licensee) may purchase the GC without applying for an NRC specific license. In the instruction manual for the GC are procedures for performing leak tests on the source at 6- month intervals, and keeping a written inventory of the device updated at 6-month intervals.

Additionally, the manual includes a statement that the GC may not be transferred or sold to anyone who does not have a specific license to possess 50 mCi of Ni-63, and that the GC can only be disposed of by shipping it back to the manufacturer.

b. Specific Licenses.

(1) Specific licenses require the submission of an application (either to the NRC or an Agreement State depending upon who has jurisdiction) and the issuance of licensing documents from the regulatory agency. It is illegal to transfer (sell or give) licensed radioactive material to another person or institution unless the recipient has a license to possess the material. Consequently, radionuclide supply companies require information about a customer's license before they will fill an order. Devices which may be specifically licensed include: gas chromatographs, moisture/density gauges, and industrial radiography cameras.

(2) Example: A district has a specific license to possess and use up to 100 mCi of Ni-63 in sealed sources. The district may have two 50 mCi sources at one time. Additionally, the specific license may contain conditions such as:

The sealed sources will be leak tested at 3-month intervals.

The source shall be used only by persons who have completed training as described in the license application.

An example of an NRC radioactive material license is included at Appendix H.

c. Exempt Quantities.

(1) A list of exempt quantities, that is, the amount of a particular radionuclide that can be obtained without a general or specific license can be found in 10 CFR 30.71, Schedule B. These NRC regulations also list exempt concentrations, that is, the concentration of a particular radionuclide in a product that can be obtained without a general or specific license. Additionally, NRC and Agreement State regulations contain a listing of exempt items, that is, items containing radioactive material that can be obtained without a general or specific license. If you are unsure of the licensing requirements for a device you wish to use, contact the Command RPO.

(2) *NOTE*: As previously mentioned, there is some radioactive material that is not regulated by the NRC, but is regulated by Agreement

States. Most Department of Defense (DOD) sites are exclusive Federal property and so are regulated by the NRC, but some bases and some portions of bases may be state property and may be regulated by the state. Always check to determine if the site you are on is Agreement State regulated. This is normally done through the Command Real Estate function and the Office of Counsel.

4-3. 'Storage Only' Licensing.

The NRC allows licensed radioactive material that is not being used to be licensed for storage only. This method of licensing is less expensive than a possession and use license. The sealed source wipe testing requirements are greatly reduced (usually, once per 10 years, prior to storage, and when removed from storage). The license may require a semi-annual inventory of all radioactive material.

4-4. Radiation Generating Devices.

The NRC does not license radiation generating (X-ray) devices since they do not contain radioactive material. Most states, however, require registration and/or licensing of radiation generating devices. States do not have authority to regulate devices used only on exclusive Federal jurisdiction facilities, but many states request that they be notified of all radioactive materials and devices located within their boundary. Facilities located on non-exclusive federal jurisdiction, may be subject to state regulation. **USACE requires that most ionizing radiation generating devices have an ARA (see paragraph 4-6).** Table 4-2 lists the state radiological health program offices to contact for registration and/or licensing of radiation generating devices.

4-5. Reciprocity Requirements.

a. The NRC and Agreement States reciprocally recognize each other’s radioactive material licenses. That is, an Agreement State licensed company can perform work in NRC jurisdiction under the company’s Agreement State license. Likewise, an NRC licensed company can perform work in an Agreement State’s jurisdiction under the company’s NRC license.

b. When a state-licensed contractor desires to perform work in an “NRC-state,” the contractor must first be granted reciprocity by the NRC. The contractor must provide the NRC with a copy of its state radioactive material license and inform the NRC of its work intentions using NRC Form 241. There is a fee for filing NRC

Form 241 which may range from $200.00 to $1000.00 or more depending on the type of license and work to be performed.

c. When a state-licensed contractor desires to work in another Agreement State, the contractor must notify the Agreement State using the appropriate state form.

d. An NRC licensed contractor performing work on a site under an Agreement State's jurisdiction must notify the Agreement State using the appropriate state form. Some Agreement States also charge a fee for reciprocity.

4-6. Army Radiation Authorization (ARA).

a. ARAs are issued by Major Army Commands (MACOM) (including the Corps of Engineers). An ARA is required for a USACE Command to receive, possess, use, or transfer radioactive material that is not licensed by the NRC, that is, NORM or NARM material or an ionizing radiation generating device. An ARA is not required for radioactive material that is covered by another MACOM’s similar authorization.

b. An ARA is not required for:

(1) NRC license exempt or generally licensed materials,

(2) less than 1.0 microcurie of NORM or NARM,

(3) less than 0.1 microcurie of radium-226,

(4) electron tubes containing less than 10 µCi (370 kBq) of any NARM radioisotope,

(5) machine-produced ionizing radiation sources not capable of producing a high or very high radiation area, and

(6) Army nuclear reactors and Army reactor-produced RAM that remains at the reactor site. The Army Reactor Office issues Army reactor permits for these sources (see AR 50-7).

4-7. Army Radiation Permits (ARP) and Other Service Installation Permits.

a. An ARP is required for a non-Army agency (including civilian contractors) to use, store, or possess ionizing radiation sources on an Army installation, facility, or project, or at a U.S. Army Reserve Center. Non-US Air Force (USAF) organizations on USAF property are required to obtain a USAF permit for use of NRC licensed material, NORM or NARM, or radiation generating devices. Concurrence of the Air Force or Navy installation commander, and/or RPO is required to obtain a base permit. “Ionizing radiation source” means any source that, if held or owned by an Army agency, would require a general or specific NRC license or an ARA.

b. The non-Army applicant will apply by letter with supporting documentation through the appropriate tenant commander to the installation commander.

c. The ARP application will specify start and stop dates for the ARP and describe for what uses the applicant needs the ARP. The installation commander will approve the application only if the applicant provides evidence to show that one of the following is true:

(1) The applicant possesses a valid NRC license or Department of Energy (DOE) radiological work permit that allows the applicant to use the source as specified in the ARP application.

(2) The applicant possesses a valid agreement state license that allows the applicant to use RAM as specified in the ARP application, and the applicant has filed NRC Form-241, Report of Proposed Activities in Non-Agreement States,(attached at Appendix H) with the NRC in accordance with 10 CFR 150.20. An ARP issued under these circumstances will be valid for no more than 180 days in any calendar year.

(3) For NARM and machine-produced ionizing radiation sources, the applicant has an appropriate state authorization that allows the applicant to use the source as specified in the ARP application or has in place a radiation protection program that complies with Army regulations.

(4) For overseas installations, the applicant has an appropriate host-nation authorization as necessary that allows the applicant to use the source as specified in the ARP application and has in place a radiation protection program that complies with Army regulations.

d. All ARPs will require applicants to remove all permitted sources from Army property by the end of the permitted time.

e. Disposal of RAM by non-Army agencies on Army property is prohibited. However, the installation commander may authorize radioactive releases to the atmosphere or to the sanitary sewerage system that are in compliance with all applicable Federal, DOD, and Army regulations.

f. *NOTE* Moisture/density gauges, X-ray fluorescence analyzers, and other similar devices require an Army or USAF radiation permit or exemption.

g. *NOTE* Any ARP should be written to allow sufficient flexibility and be as generic in nature as is possible. Once a permit is approved, the details listed MUST be adhered to with no variations allowed.

h. Installation permits need to be applied for at least 45 days prior to the start of the intended use of the materials and must be secured before radioactive material are brought onto a base.

I. An NRC licensed company must notify the RPO before bringing radioactive material onto a Navy base. A state licensed company must notify the RPO and, provide the RPO with an NRC Form 241 and a copy of the company's state radioactive material license before bringing radioactive material onto the Navy base.

4-8. Applying for an NRC License.

If it is determined that a Command needs to own radioactive material, the following steps should be followed:

a. Check with the CO to ensure that the Command will support the license and all the accompanying costs and responsibilities.

b. Find the source of funding for paying licensing, maintenance and training costs. The license alone will cost between $500 and $4000 per year. Maintaining and meeting the license conditions will depend on the type and extent of the license and can easily reach $2000 a year. Authorized Users, Authorized Users' Assistants, RPOs, etc. will require initial and annual refresher training.

c. Contact the RPSO and coordinate the licensing.

d. Obtain a copy of the NRC Form 313 "Application for Byproduct Material Usage" (attached at Appendix H). Also obtain the appropriate regulatory guide (this will depend on what radioactive material you desire and your intended use). The regulatory guide will provide good step-by-step instructions for filling out the form.

e. An example license application is included at Appendix H. Note that the application will include a copy of the Command's Radiation Protection Program, and that the license will include a condition (condition #19 in the example at Appendix H) stating that the application and all accompanying documentation will become a part of the license.

Everything that the applicant commits to in the application and subsequent correspondence will be binding in the license. Some tips which may help complete the form are as follows:

(1) In Item 5a, list each radionuclide that will be used.

(2) In Item 5b, if using sealed sources, the chemical and/or physical form is “sealed source.” List the manufacturer’s name and the model number of each source. Do not give serial numbers; allow flexibility.

(3) In Item 5c, give the maximum amount of each radionuclide that will be possessed at any given time, including all material in storage and waste.

(4) In Item 6, describe the uses in very broad terms. For example: “To be used in Troxler Model 3440 gauge to measure soil parameters at temporary job locations within the United States.”

(5) In Item 7, list no more than one individual, and, if necessary, one alternate. The individual(s) must meet the training requirements described in Chapter 2.

(6) In Item 9, be sure that the instruments listed will detect the type of radiation emitted by the radionuclides listed. Include a diagram of the work site and the radioactive material storage location when it is not in use.

(7) In Item 10, each licensee is required to have a written, site-specific, Radiation Protection Program. One method of developing this program would be to lift the applicable sections of this guidance and incorporate those sections into a manual, adding site specific emergency plans, points of contact and personnel lists.

(8) In Item 11, for sealed sources, state that "No waste will be generated. Sealed sources will be returned to the manufacturer for disposal.” If using unsealed sources, coordinate with an HP or the RPO to determine a waste disposal plan.

(9) Photocopy and keep a copy of the application and all submittals as these documents will probably be “tied down” on the license. When a document is “tied down,” it is specifically identified on the license and the regulatory agency can inspect against it, that is, the applicant must abide by all commitments made in those documents.

(10) Submit the application and any license fee

to the RPSO.

(11) The RPSO will review the application, edit as needed, and forward the application and fee to the NRC in the appropriate region.

(12) Radioactive material may not be ordered until the applicant has a copy of the radioactive material license in hand.

4-9. Applying for an ARA.

a. If it is determined that an activity needs NORM, NARM or an ionizing radiation generating device, the following steps should be followed:

(1) Check with the CO to ensure that the unit will support the permit and all the accompanying costs and responsibilities.

(2) Find the source of funding for paying maintenance and training costs. All users of the radioactive material will require initial and annual refresher training.

(3) Contact the RPSO and coordinate the licensing.

(4) Obtain DA Form 3337 "Application for Department of the Army Radiation Authorization or Permit" and "Instructions for preparing DA Form 3337" from your local forms manager. The instructions are self-explanatory. The tips in paragraph 4-8, "Applying for an NRC License" apply equally to Army permits. Copies are attached at Appendix H.

b. The application for an ARA is made by submitting DA Form 3337 to the **USACE RPSO**. The Form does **not** get sent to the address listed in the "Instructions for preparing DA Form 3337". The application will include a list of all NRC licenses and other ARAs held by the Command. Renewals or amendments will be submitted in the same manner as an original application. Requests should be submitted at least 120 days prior to expiration date. A renewal request received prior to the expiration date is considered active until the renewal approval is received.

4-10. Amendment Requests.

a. An amendment to an NRC or Agreement State radioactive material license or an ARA is necessary anytime:

(1) additional radionuclides or radioactive material of another chemical or physical form is desired;

(2) the use of radioactive material changes from the currently authorized use;

(3) the Radiation

Protection Program or waste disposal method will change substantially; and

(4) if the RPO is listed on the license by name, and a new RPO is then appointed.

b. Amendment requests are submitted in the same way as new licenses or permits. Licensees may not procure requested radionuclides or quantities until the amendment has been approved.

4-11. Renewing Licenses or ARA's.

a. Radioactive material licenses are issued for five years and must be renewed to stay in effect. The NRC will send a notice (approximately 90 days in advance) stating that the license is about to expire. It will also send the necessary forms to renew the license. License renewal requests must be submitted to the RPSO for review and forwarding at least 60 days prior to the expiration date. If sufficient time is not available to prepare the renewal request, the applicant may ask the NRC (in writing) to extend the expiration date for up to 90 days.

b. License renewal requests that are received by the NRC thirty days prior to the expiration date will be deemed "timely filed." The NRC will send a "timely filed letter". With this letter, the licensee may continue operating under the old license until they issue the renewed license. If material is needed, the supplier may ask to see this "timely filed letter."

c. If a license is not renewed in a timely manner, all radionuclide use must cease on the date of expiration. At this point, the NRC may require submission of a new license application.

d. ARAs also must be renewed every five years. The RPSO will send a notice, approximately 90 days in advance, to permit holders informing them that their ARA is about to expire.

4-12. Transfer of Radioactive Materials.

a. Should a Command wish to transfer radioactive material to another Command, a Request for Authorization to Transfer Radioactive Materials (ENG Form 4790-R) must be completed and submitted to the RPSO through command channels. A copy of ENG Form 4790-R is included at Appendix H.

b. The RPSO will review the request, and the receiving Command's radioactive license or ARA to ensure that all regulations, license or ARA conditions are met, then approve the transfer.

c. When the Command receives authorization to transfer the materials, the RPO shall ensure that the radioactive materials are packaged and shipped according to DOT and NRC regulations (see Chapter 8).

d. The RPO shall prepare a Certificate of Disposal of Materials (NRC Form 314) and forward the original to the RPSO. The RPSO will review the certificate and record the transfer in the USACE radioactive materials inventory. If the radioactive materials are listed on an NRC license, the RPSO will submit the certificate to the NRC.

4-13. Terminating a Radioactive Material License or ARA.

a. When a Command no longer wishes to possess or use licensed or permitted radioactive material, the license or ARA must be terminated. License or ARA termination involves disposal of all radioactive material, a survey of the premises for radioactive material contamination (a “close-out survey”), submission of disposal documentation and the close-out survey results, and a written request for termination of the license or ARA submitted to the RPSO. The RPSO will review the request and submit it to the proper regulatory agency or DA official for acceptance. The close-out survey must be performed in all areas that may possibly be contaminated with radioactive material. Sealed sources, that have passed semi-annual wipe tests pose little hazard of contamination and a survey of the main storage area would be sufficient. Where unsealed forms of radionuclides have been used, the survey should be conducted following NRC guidance. Nuclear Regulatory Commission NUREGs and Reg. Guides explain the required sampling and monitoring strategy for different site types, gridding methods for surveys, sample analysis, data interpretation techniques, and documentation requirements for termination surveys.

b. The license is considered formally terminated only upon receipt of the letter of termination from the NRC to the RPSO.

4-14. Information Flow through applicable USACE Channels.

a. All NRC license or ARA applications, approvals, amendments, submittals, terminations, etc., must be routed through all Safety and Occupational Health Office channels (that is, “through channels”), prior to being received for action by the HQUSACE RPSO. For example: a request to obtain an NRC license amendment would flow from the local RPO, through the local SOHO, through the Division SOHO, to the RPSO for action. Actions would be forwarded from the RPSO in reverse order.

b. Failure to follow the information flow process is a violation of the USACE delegation requirements specified by the DA. Technical consultations between NRC Offices and license holders at USACE Commands may take place, though notification of the RPSO of such communications is recommended.

TABLE 4-1
NRC Regional Offices

REGION	**LOCATION**	**TELEPHONE NO.**
Region I	King of Prussia, PA	610-337-5000
Region II	Atlanta, GA	404-331-4503
Region III	Lisle, IL	708-829-9500
Region IV	Arlington, TX	817-860-8100

TABLE 4-2
State Radiological Health Program Office and 24-Hour Phone Nos.
†Agreement State

STATE	**OFFICE PHONE NO.**	**24-HOUR PHONE NO.**
Alabama†	205-613-5391	205-242-4378
Alaska	907-465-3019	907-789-9858
Arizona†	602-255-4845	602-223-2212
Arkansas†	501-661-2301	501-661-2136
California†	916-322-3482	916-391-7716
Colorado†	303-692-3030	303-771-8517
Connecticut	203-424-3029	203-566-3333
Delaware	302-739-3787	302-678-9111
District of Columbia	202-727-7190	202-727-1010

STATE	OFFICE PHONE NO.	24-HOUR PHONE NO.
Florida†	904-487-1004	407-297-2095
Georgia†	404-362-2675	800-241-4113
Hawaii	808-586-4701	808-733-4300
Idaho	208-334-2235	800-632-2235
Illinois†	217-785-9868	217-785-9900
Indiana	317-383-6152	317-383-6154
Iowa†	515-281-3478	515-993-5386
Kansas†	913-296-1562	913-296-3176
Kentucky†	502-564-3700	502-564-7815
Louisiana†	504-765-1060	504-765-0160
Maine†	207-287-5686	207-624-7000
Maryland†	410-631-3300	410-922-7609
Massachusetts†	617-727-6214	617-727-9710
Michigan	517-335-8200	517-336-6100
Minnesota	621-627-5039	612-649-5451
Mississippi†	601-354-6657	601-856-5256
Missouri	314-751-6102	314-635-4964
Montana	406-444-3671	406-442-7491
Nebraska†	402-471-2168	402-471-4545
Nevada†	702-687-5394	702-687-5300
New Hampshire†	603-271-4588	603-271-3636
New Jersey	609-987-6389	609-292-7172
New Mexico†	505-827-4300	505-351-4651
New York†	518-458-6461	518-457-2200
North Carolina†	919-571-4141	919-733-3861
North Dakota†	701-328-5188	701-328-2121

STATE	OFFICE PHONE NO.	24-HOUR PHONE NO.
Ohio	614-644-2727	614-644-1909
Oklahoma	405-271-7484	800-522-0206
Oregon†	503-731-4014	503-731-4014
Pennsylvania	717-787-2480	717-783-8150
Rhode Island†	401-227-2438	401-621-1600
South Carolina†	803-737-7400	803-253-6488
South Dakota	605-773-3364	605-224-7888
Tennessee†	615-532-0360	615-741-0001
Texas†	512-834-6688	512-458-7460
Utah†	801-536-4250	801-533-4097
Vermont	802-865-7730	802-244-8727
Virginia	804-786-5932	804-674-2400
Washington†	360-586-8949	360-786-8001
West Virginia	304-588-3526	304-558-5380
Wisconsin	608-267-4782	800-943-0003
Wyoming	307-777-7574	Not available

Chapter 5. Dose Limits and ALARA.

5-1. Occupational Dose Limit structure.

As described in Chapter 4, doses to Authorized Users' Assistants are regulated by the NRC or Agreement State, OSHA, and DA and USACE regulations. To ensure compliance with all regulatory agencies, USACE has established a three tiered approach to worker dose limits. Tier 1 is the NRC regulatory dose limits which are never to be exceeded. Tier 2 is the USACE dose limits which are effectively 10% of the NRC limits. The USACE limits will ensure that USACE workers will be in compliance with OSHA regulations and Agreement State regulations. Tier 3 is project specific dose goals which will be set below the USACE dose limits. Project specific dose goals are used to promote the concept of ALARA; keeping the dose as low as is reasonably achievable, taking social, technical and financial considerations into account. Army and NRC regulations require a radiation protection program that promotes ALARA. Descriptions and examples of the technical definitions of the various dose items are explained in paragraph 3-5 of this manual. Table 5-1 highlights the dose limits put forth in the three-tiered approach.

5-2. USACE Dose Limits.

a. Tier 1; NRC dose limits. Each user of radioactive material or radiation generating devices shall limit occupational doses to individuals to the following limits:

(1) An annual limit which is the more limiting of:

(a) 5 rems (5000 millirem (mrem)(0.05 sieverts (Sv)) TEDE,

(b) The sum of the deep dose equivalent and the committed dose equivalent to any individual organ or tissue of 50 rems (50000 mrem)(0.5 Sv),

(c) 15 rems (15000 mrem)(0.15 Sv) to the lens of the eye, or

(d) 50 rems (50000 mrem)(0.5 Sv) shallow dose equivalent to the skin, or any extremity.

(2) The TEDE to the fetus of a declared pregnant worker will be kept below 0.5 rem (500 mrem)(0.005 Sv) during the entire gestation period. Should the worker declare pregnancy after the fetus has received 0.5 rem, the fetus will be limited to no more than an additional 0.05 rem for the remaining gestation period, as per 10 CFR 20.1208.

b. Tier 2 USACE annual dose limits. Without the written approval of the RPSO the annual occupational dose shall not exceed the more limiting of:

(1) 0.5 rems (500 mrem) (0.005 sieverts (Sv)) TEDE,

(2) The sum of the deep dose equivalent and the committed dose equivalent to any individual organ or tissue of 5 rems (5000 mrem)(0.05 Sv),

(3) 1.5 rems (1500 mrem)(0.015 Sv) to the lens of the eye,

(4) 5 rems (5000 mrem) (0.05 Sv) shallow dose equivalent to the skin, or any extremity, or

(5) The TEDE to the fetus of a declared pregnant worker will be kept below 0.5 rem (500 mrem)(0.005 Sv) during the entire gestation period. Should the worker declare pregnancy after the fetus has received 0.5 rem, the fetus will be limited to no more than an additional 0.05 rem for the remaining gestation period.

c. Tier 3 project specific dose goals. To keep doses ALARA, the user shall set administrative action levels below the USACE annual dose limits. The ALARA action levels shall be realistic and attainable. ALARA action levels can be set at any level, but need to take the particulars of each project into account. Example action levels for a small project involving little radioactive material could be:

(1)Shall not exceed the more limiting of:

(a) 0.1 rems (0.001 sieverts (Sv)) TEDE,

(b) The sum of the deep dose equivalent and the committed dose equivalent to any individual organ or tissue of 0.5 rems (0.005 Sv),

(c) 0.15 rems (0.0015 Sv) to the lens of the eye, or

(d) 0.5 rems (0.005 Sv) shallow dose equivalent to the skin, or any extremity.

Table 5-1
Dose Limits

Body Part	NRC Annual Limits	USACE Annual Limits	Example Annual ALARA Limits
Whole Body	5 rem	0.5 rem	0.1 rem

Body Part	NRC Annual Limits	USACE Annual Limits	Example Annual ALARA Limits
Individual Organ	50 rem	5.0 rem	0.5 rem
Lens of eye	15 rem	1.5 rem	0.15 rem
Skin	50 rem	5.0 rem	0.5 rem

d. Planned special exposures (see definitions) shall not be used without the written consent of the RPSO.

e. Persons under the age of 18 shall not be allowed occupational exposure to radiation on USACE sites.

f. Because the embryo/fetus is very radiosensitive, the NRC has set lower dose limits. The dose to an embryo/fetus shall not exceed 0.5 rem (0.005 Sv) during the entire gestation period. To accomplish this, and to ensure privacy and working rights, the NRC has defined regulations for the control of doses to a Declared Pregnant Worker (DPW).

(1) A declared pregnant worker means a women who has voluntarily informed her employer, in writing, of her pregnancy and the estimated date of conception.

(2) A declared pregnant worker will be provided with a declaration of pregnancy form which the RPO will use to calculate the dose received from the date of conception until the date of declaration. Exposure limits for the remaining allowable dose will be set at that time. A declared pregnant worker may “un-declare” at any time.

(3) The RPO will give the DPW a copy of the DPW statement (see Appendix H for an example (if Social Security Number is used, ensure proper privacy act statement is included)), a copy of NRC Regulatory Guide 8.13, and enroll the DPW in a fetal monitoring program (See chapter 7).

5-3. <u>NRC and Agreement State Dose Limits.</u>

a. NRC dose limits are the Tier 1 limits. NRC regulates only NRC licensed source, byproduct or special nuclear materials. Most Agreement States have the same dose limits as the NRC, but most include regulation of NORM and NARM materials and radiation generating devices.

b. Under NRC regulations,

each user of licensed radioactive material shall limit occupational doses to individuals as stated in paragraph 5-2a.

c. Note that compliance with the USACE dose limits will comply with the NRC and Agreement State dose limits.

5-4. OSHA Dose Limits.

a. OSHA adopted the NRC dose limits as they were written before the new 10 CFR 20 was issued in 1991. Note that OSHA regulations apply to all radioactive materials including NORM and NARM, as well as radiation generating devices such as X-ray machines.

b. No employer shall use radioactive materials or radiation generating devices in a manner which would cause any individual to receive a dose during one calendar quarter in excess of:

(1) 1.25 rem to the whole body; head and trunk; active blood forming organs; lens of eyes or gonads.

(2) 18.75 rem to the hands and forearms; feet and ankles.

(3) 7.5 rem to the skin of the whole body.

Note that compliance with the USACE dose limits will meet this requirement.

5-5. Monitoring Requirements.

Both OSHA and NRC have requirements to monitor dose to individuals who can reasonably be expected to receive a dose greater than 10% of the maximum permissible dose. Compliance with USACE Tier 2 dose limits will keep workers at doses below 10% of the maximum permissible doses. The RPO will issue dosimetry to occupationally exposed individuals as deemed necessary to demonstrate compliance with Federal, Army and USACE regulations, and to ensure that doses are kept ALARA.

5-6. Doses to the Public.

a. NRC and Agreement States presently require that a licensee restrict dose to the public to 100 mrem/year TEDE from licensed activities. The EDE in any unrestricted area may not exceed 2 mrem in any one hour. The maximum allowable dose to the public from effluents from a licensed facility is 50 mrem/year and listed in Appendix B of 10 CFR 20 as a calculated concentration for each specific radionuclide yielding 50 mrem/year. For decontaminated and decommissioned facilities to be released without restrictions, the dose from residual contamination must be below 25 mrem/year to the public.

b. The EPA has standards for radioactivity in community drinking water systems. The present standards are 5 picocuries per liter (pCi/l) of Ra-226 plus Ra-228, and 15 pCi/l of gross alpha particle activity, including Ra-226 but excluding uranium and radon. The present dose limits are 4 mrem/year from beta/gamma-emitting radionuclides to the whole body or any organ.

c. There are proposed rules from both the NRC and the EPA to limit dose to the public from radiation to 15 mrem/year. Note that this value is so far below natural background levels as to be unmeasurable by any instrumentation and only calculable through dose modeling.

Chapter 6. Working with radiation.

6-1. Caution Signs and Labels.

a. Appropriate warnings are required in all areas, rooms, and on all containers in which significant amounts of radiation or radioactive material may be found. Warnings consist of postings and labelings. In general, areas or rooms are "posted" with signs whereas containers, devices, equipment, etc. are "labeled." The specific warning to be used depends on the type and degree of hazard present. The RPO will post rooms, hoods, work areas, etc. The AU is responsible for appropriate labeling.

(1) Posting Caution Signs.

(a) USACE policy is that any room or area in which radioactive material, covered by an NRC license, an Agreement State license, or an ARA is used or stored shall be posted "Caution, Radioactive Material".

(b) A room or area in which radioactive material is used or stored may require additional posting if the dose rate in the room or area is likely to exceed 5 mrem in any one hour at 30 cm from the source or source container. Table 6-1 specifies when a room or area must be posted as a Radiation Area, a High Radiation Area, or a Very High Radiation Area.

Table 6-1
Caution Sign Posting Requirements

Dose Rate	Distance From Source	Posting Required
1. 5 mrem in any one hour.	1. 30 cm	1. "Caution, Radiation Area"
2. 100 mrem in any one hour.	2. 30 cm	2. "Caution, High Radiation Area"
3. 500 rad in any one hour.	3. 1 m	3. "Grave Danger, Very High Radiation Area"

(2) NRC Required Labeling.

(a) When a container has a quantity of radioactive material equal to or greater than that listed in 10 CFR 20 Appendix C, a "Caution, Radioactive Material" label will be affixed to the outside of the container. Most gauges and instruments containing radioactive material, such as soil density gauges, electron capture sections of gas chromatographs, or sediment density probes will require this label. The label should be large enough to be conspicuous. Standard labels are roughly 4" x 3.5".

(b) Each AU shall, prior to disposal of any uncontaminated empty container to an unrestricted area, remove or deface the label or otherwise clearly indicate that the container no longer contains radioactive material.

(c) Be advised that this labeling requirement is separate from the labeling requirements of DOT. A package of radioactive material prepared for transportation may also need DOT labels as described in Chapter 8 - Transportation of Radioactive Material.

(d) An AU is not required to label containers when they are attended by an individual who takes the precautions necessary to prevent the exposure of any individual to radiation or radioactive material in excess of the limits when they are in transport and packaged and labeled in accordance with DOT regulations, or containers which are accessible only to individuals authorized to handle or use them or to work in the vicinity thereof, provided that the contents are identified to such individuals by a readily available written record.

b. Signs and labels shall have a yellow background with a magenta or black standard radiation symbol. Lettering shall be magenta or black, but magenta is the preferred color.

c. Regulations require that the following information be posted in a prominent location, in sufficient numbers to be accessible to all who work in, or frequent, areas where radioactive material is used:

(1) A copy of the license or permit, conditions, references and amendments. This is usually accomplished by posting a notice of where the license, license conditions, referenced documents and amendments are kept. For

example, "NRC License documents are kept in the District Safety Office and may be viewed by anyone upon request."

(2) Applicable operating procedures for the prescribed use of radioactive material.

(3) All notices of violations involving working conditions, civil penalties, or order, and the response from the licensee. These notices must be posted within two working days of their receipt and must be posted for a minimum of five working days or until the violation has been corrected whichever is later.

(4) NRC Form 3, "Notice to Employees" most recent version (rev. Jan 96 as of this printing), or Agreement State equivalent. (NRC Form-3 included at Appendix H.)

6-2. Airborne Radioactivity.

a. If the activities you are engaged in are suspected to create airborne radioactivity (for example, vapors or aerosols), the RPO or HP can conduct the appropriate surveys and calculations to determine if posting the area is required. If necessary, these areas will be posted with a "Caution, Airborne Radioactivity Area".

b. The RPO will arrange a time to conduct the posting of each authorized use location prior to approving that location for radioactive material use. A facility posting checklist is utilized to document postings.

6-3. Rooms/Areas in Which Radioactive Material is No Longer Used or Stored.

The AU is responsible for notifying the RPO by memo when radioactive material usage in a room or area has ceased. The RPO will perform a close-out survey of the area to ensure no residual contamination, remove all signs and postings, document the survey and, if necessary, apply to amend or terminate all applicable NRC Licenses and/or ARAs.

6-4. Receiving Radioactive Material.

a. NRC regulations require that written instructions for receiving and opening packages be maintained and followed by all personnel receiving radioactive material. Refer to 10 CFR 20.1906 for complete guidance. The following written instructions meet the NRC requirements.

b. When a package is received it will be inspected as follows:

(1) A visual check is made to see if the package is damaged (wet or crushed). If

there is evidence of degradation of package integrity, the package will be wipe tested for radioactive contamination and radiation levels.

(2) Wipe test the external surfaces of a labeled package (a package labeled with a Radioactive White I, Yellow II, or Yellow III label as specified in DOT regulations, 49 CFR 172) for radioactive contamination unless the package contains only radioactive material in the form of gas or in special form as defined in 10 CFR 20 or any package that appears damaged, or if the wipe test results from the shipper are not documented.

(3) Survey the external surfaces of a labeled package for radiation levels unless the package contains quantities of radioactive material that are less than or equal to the A_2 quantity listed in 10 CFR 71 Appendix A, and the radioactive material is in the form of a gas or in special form. Tables 6-2 and 6-3 list some of the common A1 (special (sealed source) form) and A2 (normal, unsealed form) values. All the A1 and A2 values can be found in 49 CFR 173.35. Surveying and wipe testing shall be performed as soon as practicable after receipt of the package, but not later than three hours after the package is received if it is received during normal working hours, or not later than 3 hours from the beginning of the next working day if it is received after normal working hours.

(4) The receiver will immediately notify the final delivery carrier and, by telephone and telegram, mailgram, or facsimile, the RPSO, and the NRC when removable radioactive surface contamination exceeds 2200 disintegrations per minute (dpm)/100 cm^2 beta, gamma or 220 dpm/100 cm^2 alpha or if the external radiation level exceeds 200 mrem per hour at any point on the external surface of the package or 10 mrem per hour at 1 meter from the package.

(5) When a radioactive material package is received, there is a chance the radioactive material has leaked out of the inner container. One could receive a radiation exposure if a contaminated package is opened without taking proper precautions. Always assume a radioactive material package is contaminated until proven otherwise.

c. SOPs for opening packages should be developed for each site receiving and opening radioactive material packages. The following guidance may assist in preparing the procedure:

(1) wear gloves.

(2) check to be sure the contents match the packing slip.

(3) remove and wipe test the inner container if contamination is suspected. Do not release the contents until the wipe test results have been obtained.

(4) if contamination is not found, store the radioactive material in a secure storage area that is conspicuously posted for radioactive material, as required above.

(5) if contamination is found, dispose of all contaminated shipping material as radioactive waste. If the radioactive material is still usable, clean the outside of the container, and store in an area posted as necessary, for radioactive material. Survey the receipt area for contamination.

(6) deface or remove all labels on the uncontaminated shipping box and dispose of as normal trash.

Table 6-2
Typical A_1 Quantities in Special (sealed source) Form:

H-3	1000 Ci	Ba-133	40 Ci
C-14	1000 Ci	Cs-137	30 Ci
Na-22	8 Ci	Pm-147	1000 Ci
P-32	30 Ci	Tl-204	300 Ci
S-35	1000 Ci	Po-210	200 Ci
Co-57	90 Ci	Ra-226	10 Ci
Fe-59	10 Ci	Th-232	unlimited
Co-60	7 Ci	U-238	unlimited
Ni-63	1000 Ci	Am-241	8 Ci
Sr-90	10 Ci	Cf-252	2 Ci
I-125	1000 Ci		

Table 6-3
Typical A_2 Quantities in Normal(unsealed) Form:

H-3	20 Ci	Cf-252	0.009 Ci
C-14	60 Ci	Ba-133	10 Ci
Na-22	8 Ci	Cs-137	10 Ci
P-32	30 Ci	Pm-147	25 Ci
S-35	60 Ci	Tl-204	10 Ci
Co-57	90 Ci	Po-210	0.2 Ci
Fe-59	10 Ci	Ra-226	0.05 Ci
Co-60	7 Ci	Th-232	unlimited
Ni-63	100 Ci	U-238	unlimited
Sr-90	0.4 Ci	Am-241	0.008 Ci
I-125	70 Ci		

6-5. Radioactive Material and Radiation Generating Device Inventory.

a. The RPO for each USACE Command is responsible for all radioactive material and radiation generating devices owned or possessed by the Command, regardless of whether the material and radiation generating device is authorized under a general license, a specific license, or ARA. In order to ensure control of all radioactive material and radiation generating devices, the RPO shall maintain a written inventory of all radioactive material and radiation generating devices within the Command. Inventory should be categorized into NRC specifically licensed materials, NRC generally licensed materials, ARA authorized materials, and radiation generating devices. The inventory shall be kept on ENG Form 3309-R “Record of Radioactive Material”. A copy of this form is attached at Appendix H.

b. The RPO for each Command owning or possessing radioactive material or radiation generating devices shall physically inventory each item at least semi-annually, and more often if their license requires it. This will usually be accomplished along with the semi-annual wipe test. For remote sources, such as those assigned to dredges, the RPO may have an AU perform the physical inventory of the item(s).

6-6. Storing Radioactive Material.

The AU is responsible for assuring that all radioactive material is stored in a secure manner when not in use. Sealed sources used in the field may be locked in their storage containers. Sealed sources stored in a building may be locked in a storage room or storage cabinet. Unsealed sources may be locked in a storage container, cabinet, drawer, refrigerator, or freezer. Labs where unsealed sources are used shall be locked whenever the lab is unattended. Sealed sources in fixed use locations may be secured in their work position. The AU must ensure that where ever radioactive sources are stored, proper labeling and posting, as per paragraph 6-1 is used.

6-7. Contamination Control.

a. Depending upon the types and quantities of radioactive material in use, contamination surveys may be made directly with portable survey instruments or indirectly (removable contamination survey, wipe or swipe survey) by wiping surfaces (approximately 100 cm^2) with a filter paper and counting the wipes.

A direct contamination survey is performed using a meter and detector appropriate to the nuclides in use in the area. For example, if surveying for P-32 contamination, one would use a GM detector (probe); for I-125, one would use a thin window NaI scintillation detector (probe). An ionization chamber would not be appropriate for a contamination survey. At the beginning of each day of use, an instrument’s operability should be checked with a suitable check source. Each meter has an integrator circuit and it will take time for it to properly respond. It is highly suggested that meters be equipped with audio circuits so a surveyor can hear a change in 'click' rates and resurvey suspected 'hot spots'.

b. Removable contamination consisting of low energy beta or alpha emitting radionuclides, such as H-3, C-14, or Pu-239, is best detected through the use of wipes and liquid scintillation counting since the beta emissions from these radionuclides have insufficient energy to be efficiently detected by portable survey instruments, and the alpha emissions have of too short of a range in air to be easily detected. Wipes may also be appropriate when attempting to detect contamination in areas with higher than background radiation levels. For example, the use of a GM survey meter to detect contamination would not be practical if radiation levels in an area are already elevated from radioactive material stored within the area. In this situation, a wipe test could be performed and the wipe counted at a location away from the radiation field.

c. When radiation levels in an area are normal background, portable survey instruments can be quite effective in detecting certain types of radioactive contamination. Most GM meters can detect P-32 with efficiencies exceeding 20%. I-125 can be detected at efficiencies nearing 20% with a thin crystal (NaI) scintillation probe. All survey instruments are only as good as their maintenance. A portable survey meter, in most cases must be calibrated at least once every year and operability verified each day of use with a check source.

6-8. <u>Wipe Tests.</u>

a. A wipe test, also called a 'smear' or 'swipe' test, is collected using various materials. The most common material is a filter paper type material designed specifically for this purpose. This material can be used wet or dry but dry wipe tests are preferred. Dry tests are preferred if the chemical form of the radionuclide is not known. If it is not water soluble, a wipe with a wet swab will not collect as much of the contaminant as a dry swab. Conversely, if a swab is wetted with an oil based solvent, water soluble contaminants will not be collected as efficiently. Additionally, many solvents are hazardous materials, and should radioactive contamination be found, the swab may become a mixed or commingled waste. The wipe test is performed by physically wiping the area to be checked.

b. If water is used to moisten the material, caution must be used to not saturate the material and to allow the material to dry prior to measurement. Water will attenuate alpha emitters and allow for false readings when read with a survey meter or some counting systems. The NSN for a box of 500 wipe testers is 6665-01-198-7573 (a 2-inch diameter Whatman filter paper works well also). Another common method for small spaces is the use of cotton swabs, similar to 'Q-tips.' A NSN for a package of these is 6515-00-890-1475.

c. Wipe testing is performed by using the wipe or filter paper or cotton swab and wiping it over an area approximately 100 square centimeters. Wipe tests are performed using normal finger pressure on a dry filter paper or swab and wiping in an "S" shape for a distance of 50 centimeters and wiping again in a backwards "S" shape at right angles to the first one for another 50 centimeters. The wipe is then analyzed on site or packaged in an envelope and sent to a lab for analysis. If an item is too small or irregularly shaped for this procedure, then wipe the entire surface area of small items or an accessible 100 square centimeter area of irregular shaped items.

d. Suggested limits for removable contamination are listed in Table 6-4. Whenever radioactive contamination is found, reasonable efforts should be made to remove all contamination.

6-9. Leak Testing.

a. Many sealed sources are required by license or authorization conditions to be leak tested periodically. Leak tests are typically required every six months. But some license conditions may require more frequent testing. A leak test is performed in a manner similar to a wipe test. The primary difference is that most sealed sources emit much more radiation than most contamination, and for ALARA purposes it is best to keep as much distance between the source and the person performing the leak test. This is done by using long handled cotton swabs or forceps to hold the filter paper swab, increasing the distance between the source and the hand. The wipe, or swab should then be placed in its own plastic bag or glycine envelope to avoid potentially contaminating other wipes or areas. Since many Commands do not have the instrumentation available to determine the amount of contamination from a leak test, most leak test wipes are sent to a lab for analysis. USACE leak tests shall be sent to USAIRDC for analysis.

b. The limits for contamination of sealed sources is 0.005 μCi per wipe.

Table 6-4
Acceptable Surface Contamination Levels

NUCLIDE [a]	**AVERAGE** [b c] dpm/100 cm^2	**MAXIMUM** [b d] dpm/100 cm^2	**REMOVABLE** [b e] dpm/100 cm^2
U-nat, U-235, U-238 and associated decay products	5,000 þ	15,000 þ	1,000 þ
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	100	300	20
Th-nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	1,000	3,000	200
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above.	5000 ß-þ	15,000 ß-þ	1,000 ß-þ

[a] Where surface contamination by both alpha- and beta-gamma-emitting nuclides exists, the limits established for alpha- and beta-gamma-emitting nuclides should apply independently.

[b] As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

[c] Measurements of average contaminant should not be averaged over more than 1 square meter. For objects of less surface area, the average should be derived for each object.

[d] The maximum contamination level applies to an area of not more than 100 cm^2.

[e] The amount of removable radioactive material per 100 cm^2 of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of less surface area is determined, the pertinent levels should be reduced proportionally and the entire surface should be wiped.

6-10. Exposure Rate Surveys.

In addition to contamination monitoring, it is also important to assess exposure rates resulting from the storage and use of relatively large quantities of high energy beta or gamma emitters. This information is important in planning and evaluating the control of time, distance, and shielding in order to minimize personnel exposure. In some situations, a GM meter calibrated at or near the energy of the radiation measured, can give a reasonable estimate of the exposure rate. An ionization chamber will give the most accurate estimate of exposure and should be used whenever measuring exposures to determine posting requirements, measuring the transport index (TI) of a package, or when exposures are more than a few millirems.

6-11. Accident/Incident Response.

a. There is always a possibility of an accident involving radiation or radioactive material. USACE will strive for a zero accident tolerance level. This can be accomplished using Standing Operating Procedures, conscientious work practices, and having and practicing an Accident / Emergency Response Plan. The plan, required for all HTRW sites, must provide guidance for response to fire, natural disasters, radioactive material spill, and inadvertent radiation exposure. The plan will address the following procedures:

(1) Evacuation of the building/area;

(2) Treatment of injured personnel;

NOTE Never delay treatment of an injured person because of actual or potential radioactive contamination.

(3) Firefighting;

(4) Spill response;

(5) Personnel decontamination; and

(6) Any additional site specific requirements.

6-12. Accident/Incident Reporting.

a. Any individual suspecting or knowing of an accident, incident, loss or theft involving radioactive material or radiation will notify the RPO as soon as possible. The RPO will notify the RPSO immediately of any accident, incident, loss or theft that requires reporting to the NRC or other regulatory agency. The RPO will notify the NRC, OSHA or other regulatory agency in the required time frame, of all accidents, incidents, losses or thefts that require reporting. The RPSO will notify HQDA (DACS-SF) of all NRC, OSHA or other agency notifications within the same time frame as required by the agency. The RPSO will also notify DASG-PSP of all exposures exceeding Tier 1 dose limits or OSHA dose limits and submit copies of reports to other agencies to

DASG-PSP as required by the Army Radiation Protection Program. All telephone reports will be followed up by a written report within 30 days.

b. All written reports will address the following items:

(1) A description of the material involved, including the kind, quantity and chemical and physical form of the material,

(2) A description of the circumstances surrounding the incident,

(3) A statement of the disposition, or probable disposition of the material involved,

(4) An estimate of doses received by any individuals, and the circumstances of the exposure,

(5) Actions taken, and

(6) Procedures or measures proposed or adopted to prevent recurrence.

c. The following are some of the reportable accidents/ incidents, and the required reporting times:

(1) Theft or loss of 1000 times the 10 CFR 20, Appendix C quantity of a radioactive material must be reported immediately;

(2) Theft or loss of 10 times the 10 CFR 20, Appendix C quantity of a radioactive material must be reported within 30 days;

(3) Incidents that cause or threaten to cause an individual to receive 25 rem TEDE, 75 rem EDE, or 250 rem Shallow Dose Equivalent (SDE), must be reported immediately;

(4) A release of radioactive material, either inside or outside a restricted area, that could possibly result in a 24-hour dose of greater than five times the annual limits must be reported immediately;

(5) Incidents that cause or threaten to cause an individual to receive 5 rem TEDE, 5 rem EDE, or 50 rem SDE, must be reported within 24 hours;

(6) Release of radioactive material, either inside or outside a restricted area, that could possibly result in a 24 hour dose of greater than the annual limits must be reported within 24 hours.

(7) Incidents that cause an occupational worker, member of the public, a minor or an embryo/fetus of a declared pregnant woman to receive a dose in excess of the

appropriate regulatory dose, must be reported within 30 days;

(8) A release of radioactive material, inside a restricted area, greater than the license limits must be reported within 30 days;

(9) A release of radioactive material, outside a restricted area, greater than 10 times any license limit, regardless of any exposure to an individual, must be reported within 30 days.

d. Reports must include the information required in 10 CFR 20 Subpart M, or as required by other regulatory agencies.

6-13. Audits and Reviews.

a. The RPSO, or their designee, will audit each Command that possesses a radioactive material license or ARA tri-annually. The audit is to ensure personnel safety and compliance with regulatory requirements. The audit may consist of a records review, facility inspection, interviews with the RPO and AUs, and an exit interview with the RPC or the Commander, depending on the activity at the Command. The audit will be documented and a copy furnished to the Commander and the RPO.

b. The RPO will review their Radiation Protection Program annually for content and implementation. The RPO will assure that the quality and timeliness of their program meet the radiation safety guidelines outlined in this manual. The RPO will review all work with radiation within his/her Command. The RPO will perform the annual review with the purpose of anticipating the needs of the program in the coming year. The review will be documented and a copy forwarded to the RPSO.

c. Additional audits and reviews may be performed as deemed beneficial to the Command by the RPSO, the RPO, or the Commander.

d. Documentation Audits. Documentation audits may be performed by the RPSO or their designee for Commands with an NRC license or ARA where little health risk is posed by radiation. A document audit will consist of a review of the radioactive materials license or ARA, the inventory, personnel dose histories, receipt, transfer, and disposal records, and leak test results. Deficiencies may include incomplete or inaccurate documentation. Significant or multiple deficiencies may initiate a field audit.

e. Field Audits. Field audits will be performed by the RPSO or their designee for

Commands where the use of radioactive materials or radiation generating devices has the potential to present greater health risks to USACE personnel or the public. A field audit will consist of a documentation audit and an on-site inspection. The inspection will concentrate on proactive radiation protection procedures and processes. These may include:

(1) ensuring proper posting and labeling,

(2) ensuring proper use of dosimetry,

(3) ensuring proper and secure storage of radioactive materials,

(4) ensuring that radiation monitoring equipment is of the proper type for the radiation used; that the instruments have been calibrated in a timely manner; and that personnel know the correct methods of surveying for radiation and contamination,

(5) ensuring that any transportation of radioactive materials complies with NRC and DOT regulations.

f. U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) Surveys. Presently, USACHPPM surveys USACE Commands annually. USACHPPM surveys follow a sample protocol/checklist presented at Appendix I.

Chapter 7. Personnel Monitoring.

7-1. External Monitoring.

a. To indicate the amount of radiation to which a person has been externally exposed, an individual monitoring device may be used. NRC regulations define an "individual monitoring device" as a device designed to be worn by a single individual for the assessment of dose equivalent. Examples of dosimeters include film badges, thermoluminescent dosimeters (TLDs), pocket ionization chambers ("pencils"), alarm rate meters, track etch dosimeters, and neutron sensitive film. NRC and OSHA regulations require that each *licensee* monitor occupational exposure to radiation and supply and require the use of dosimeters by:

(1) Adults likely to receive in one year from sources external to the body a dose in excess of 10 per cent of the limits specified in Chapter 4;

(2) Declared pregnant women likely to receive during the pregnancy, from sources external to the body a dose in excess of 10 per cent of the limits in Chapter 4; and

(3) An individual entering a high or very high radiation area.

b. Most individuals who work in radiation areas never approach values which require personnel monitoring. Statistical evaluations of monitoring results have shown that 70% of all monitored Authorized Users' Assistants receive no measurable exposure and another 20% receive less than 100 mrem per year. Exposure histories have documented the fact that usually only those individuals who work in radiology, radiography, and other fields using high activity sources are required to be monitored.

c. Within USACE, the RPO will determine which USACE personnel should wear dosimeters. USACE personnel are among the aforementioned large percentage of individuals which are not likely to receive a measurable dose. Dosimetry is issued, in most cases, to document low exposures.

d. The RPO will instruct personnel in the proper use of dosimeters, will issue dosimeters, will collect dosimeters and submit them for analysis, and will review the analysis results. Dosimeters (except direct and indirect reading pocket ionization chambers) will be processed by a laboratory which holds current accreditation from the National Voluntary Laboratory Accreditation Program (NVLAP) of the National Institute of

Standards and Technology (NIST).

e. Most contractors use vendor supplied services. **USACE personnel will use the US Army Ionizing Radiation Dosimetry Center (USAIRDC) for dosimetry services.** Exposures shall be reported and recorded. Exposures shall be recorded using the computer generated printout generated by USAIRDC or NRC Form 5 (a copy for reference of the USAIRDC version of NRC Form 5 is attached at Appendix H). The program is administered from Redstone Arsenal and may be contacted at the following:

US Army Missile Command
Attn: AMSMI-TMDE-SR-D
Redstone Arsenal, AL 35898-5400
commercial phone number: (205)876-1858.

f. The four chip TLD is the standard US Army whole body dosimeter.

g. Personnel should not expose their dosimeter to security X-ray devices, excessive heat, or medical sources of radiation. Should job conditions dictate, dosimeters may be removed from a job site as part of an employee’s routine travel to and from work. At sites where dosimeter use is routine, and there is a responsible individual to manage the dosimeters, the personal dosimeters should be stored at site and not taken home each night. A dosimeter shall be returned to the RPO if an employee will not be physically present at the job site for a period of one month or greater.

h. A person whose dosimeter is lost, damaged, or contaminated while working will immediately exit the radiation control area and report the occurrence to the RPO. Reentry of the person into the radiation control area will not be permitted without RPO approval. Dosimeters will not be utilized by USACE personnel for operations at locations other than USACE sites.

7-2. Internal Monitoring.

a. NRC regulations also require that each licensee monitor the occupational intake of radioactive material by and assess the committed effective dose equivalent to:

(1) Adults likely to receive in one year an intake in excess of 10 percent of the applicable ALI; and

(2) Declared pregnant women likely to receive during the pregnancy, a committed effective dose equivalent in excess of 50 mrem.

b. If a licensee is required to monitor both external and internal exposures, then the external and internal doses must be summed to demonstrate compliance with the dose limits specified in Chapter 5.

c. Internal monitoring can be achieved via bioassay. A bioassay is a determination of the kind, quantity, or concentration and location of radioactive material in the body. A direct (*in vivo*) bioassay measurement may be made by whole body counting (that is, counting the gamma-rays emanating from a radionuclide in a given organ). An indirect (*in vitro*) bioassay measurement may be made by assessing the quantity of a specific radionuclide in samples that are excreted (for example, urine, feces, or blood). There are four types of bioassays:

(1) Baseline: Prior to potential exposure;

(2) Routine: At a specified frequency (for example, quarterly);

(3) Postoperational: Within two weeks of the last possible exposure when operations are being discontinued or when the worker is terminating duties with exposure to radioisotopes; and

(4) Diagnostic: Follow-up bioassay performed within two weeks of any measurement exceeding the action level. This will confirm the preceding measurement and allow an estimate of effective half-life.

d. Within USACE, personnel shall participate in a bioassay program when they are likely to receive an intake that may result in a committed effective dose equivalent of 100 mrem or more, or, when an intake of radiation is suspected for any reason. Specific bioassay requirements will be determined by the RPO for each job site. Bioassay procedures, supplies, lab analysis and dose assessment may be obtained on a cost reimbursable basis from the US Army Center Health Promotion and Preventive Medicine (USACHPPM), Radiochemistry and Analysis Program (RAP), commercial phone,(410) 671-3983.

e. Personnel shall be notified promptly of positive bioassay results, as well as the results of dose assessments and subsequent refinements. Dose assessment results shall be provided in terms of mrem to the organ(s) and whole body.

f. Personnel should participate in diagnostic (follow-up) bioassay monitoring when their routine bioassay results indicate an intake in the current year with a committed effective dose equivalent of

100 mrem or more.

g. Management should require a post-operational bioassay when a person who participated in the bioassay program terminates employment or concludes work involving the potential for internal exposure.

7-3. Advanced Monitoring.

a. Multiple dosimeters may be issued to personnel to assess whole-body exposure in nonuniform radiation fields or as required in radiation work plans. Nonuniform radiation fields exist when the dose to a portion of the whole body will exceed the dose to the primary dosimeter by more than 50 percent, and, the anticipated whole-body dose is greater than 100 mrem.

b. The use of an alarm rate meter is encouraged for entry into a high radiation area or when a planned dose of greater than 100 mrem in one week is expected. An alarm rate meter provides an early warning of elevated exposure through the use of a preset dose rate or an integrated dose. A direct reading (pencil) dosimeter may be used in place of an alarm rate meter. A pencil dosimeter with the lowest range applicable (typically 0-200 mR) should be selected. The alarm rate meter or the pencil dosimeter should be worn simultaneously with the primary dosimeter. The alarm rate meter or pencil dosimeter should not be allowed to exceed 75 per cent of full scale.

c. The establishment and maintenance of a comprehensive area monitoring program may minimize the number of areas requiring the issuance of personnel dosimeters, and, demonstrate that doses outside radiation work areas are negligible. Minimizing the number of personnel dosimeters issued lowers the costs of operating the dosimetry program and reduces costs associated with maintaining personnel with enhanced training and qualifications.

d. Area-monitoring dosimeters should be used in controlled areas to supplement existing monitoring programs, and to provide data in the event of an emergency. Area-monitoring dosimeters should be used to record and document radiation levels in routinely occupied areas that are adjacent to areas where radiation, or operations with radiation exist. Area-monitoring dosimeter results could be used to support dosimetry investigations if personnel express concerns about their work environments and possible exposure to ionizing radiation.

e. Any pregnant worker who

wishes to voluntarily enroll in the fetal monitoring program needs to contact the RPO.

(1) The worker will be provided with a declaration of pregnancy statement which the RPO will use to calculate the dose received from the date of conception until the date of declaration. An example of this statement is included at Appendix H (if Social Security Number is used ensure proper privacy act statement is provided). Exposure limits for the remaining allowable dose will be set at that time.

(2) A copy of the completed declaration of pregnancy statement, NRC Regulatory Guide 8.13, and a fetal monitoring dosimeter will be provided to the declared pregnant worker as soon as practical. The fetal monitoring dosimeter is to be worn at waist level versus the standard whole body dosimeter which is worn at the collar. If a lead apron is utilized, the fetal dosimeter is worn under the apron and the whole body dosimeter outside the apron.

(3) The exposure levels for fetal monitoring dosimeters will be closely evaluated throughout the entire gestation period by the RPO. A fetal ALARA level has been set by the RPSO at an exposure of 40 mrem/month. Should this level be exceeded, the declared pregnant worker will receive immediate notification, and actions will be taken to reduce any further exposure.

(4) At the end of the pregnancy, or if the worker rescinds her pregnancy declaration and wishes to cease fetal monitoring, the declared pregnant woman should contact the RPO to discontinue the fetal monitoring dosimeter. A fetal exposure final report will be generated.

7-4. <u>Exposure Reporting.</u>

a. The RPO will furnish each worker annually with a written report of the worker’s dose.

b. At the request of a worker who is terminating employment, the RPO will provide (within 30 days of the request) a termination report regarding the radiation dose received by that worker for the current year or fraction thereof. If the most recent results are not available at that time, a written estimate of the dose will be provided with a clear indication that this is an estimate. The RPO can obtain this information from USAIRDC.

c. It is each individual’s responsibility to notify the RPO when they terminate work involving radiation exposure.

d. A worker formerly engaged in activities controlled by USACE, may request a written report of his/her exposure to sources of radiation for each year that he/she was monitored. The report will be prepared by the RPO, will cover the period of time that the worker's activities involved exposure to radiation, will include the dates and locations of work, and will be furnished to the worker within 30 days of the request. The RPO can obtain this information from USAIRDC. The RPO can provide a detailed interpretation of a monitoring report form. Information which may be useful when reading a monitoring report is as follows:

(1) A **HARD** exposure relates to the whole body exposure (DDE);

(2) A **SOFT** exposure relates to a skin exposure (SDE);

(3) An **EYE** exposure relates to an exposure to the lens of the eye (Lens Dose Equivalent); and

(4) A dose of 000.000 or 'M' indicates a minimum reading. This means the dose for the monitoring period was below the minimum measurable quantity for the type of dosimeter used. Usual minimum values are as follows:

(a) Whole Body Badge - 10 mrem for X-and gamma-radiation, 40 mrem for energetic beta radiation; and

(b) Ring Badge - 10 mrem for X- and gamma-radiation, 30 mrem for energetic beta radiation.

e. Each RPO has information relevant to enrolling in the program. A DD Form 1952 (available through the local forms manager) must be completed and forwarded to the RPO.

f. All individuals must provide a dose history to the RPO if they are likely to have received in excess of 10% of any applicable annual limit. Additionally, any individual who had been monitored at another facility during the current calendar year must provide the RPO with pertinent exposure data. This exposure data will allow adjustments to be made so that the annual dose limits are not exceeded. Both of these are required prior to enrolling in the dosimetry program.

g. All personnel requiring bioassays will be sent a copy of their bioassay results on an annual basis. An individual may request the result of any bioassay at any time.

Chapter 8. Transportation of Radioactive Material.

8-1. Purpose.

This chapter is intended to introduce containment, control, and communication requirements when transporting radioactive material. This chapter is not an exhaustive review of all regulatory requirements which pertain to shipping radioactive material.

8-2. Applicability.

This chapter applies to all personnel who ship or transport radioactive material and all personnel who supervise operations which involve shipments or transportation of radioactive material.

8-3. Regulations.

a. The transportation of radioactive material is regulated jointly at the Federal level by the DOT and the NRC. The division of responsibilities between DOT and NRC is specified in a memorandum of understanding. DOT regulates shippers, carriers, Type A packages and LOW SPECIFIC ACTIVITY (LSA) packages, and it issues Certificates of Competent Authority for International Shipments. Relevant DOT regulations may be found in 49 CFR 170-189.

b. NRC regulates Type B and fissile packages; it is responsible for transportation safeguards; it investigates accidents/incidents, and it is a technical advisor to DOT. Relevant NRC regulations may be found in 10 CFR 71. It is worth noting that 10 CFR 71.5 requires NRC licensees to comply with 49 CFR 170-189.

c. DOE controls and regulates shipments of U.S. Government program related nuclear materials. DOE requires shippers and carriers of non-weapons under their authority to conform to DOT and NRC regulations.

d. U.S. Postal Service (USPS) regulations for mailable radioactive material may be found in USPS Publication 6, latest edition (March 1990)- “Radioactive Material.” Mailable packages are limited to those meeting DOT requirements in 49 CFR 173.421 and 173.422 for Limited Quantities and Instruments and Articles EXCEPT THAT the radioactivity content in the package is further limited to one-tenth of DOT limits in Table 7, 49 CFR 173.423.

e. For purposes of transportation, radioactive material is defined as any material which has a specific activity greater than 0.002 μCi/g (70 Bq/gm) [49 CFR 173.403 and 10 CFR 71.10(a)].

f. Hazardous material is defined by DOT as any substance, including mixtures and solutions of substances, which the Secretary of Transportation has determined to be capable of posing an unreasonable risk to health, safety and property when transported in commerce (49 CFR 171.8). Radioactive material is considered hazardous material by DOT's definition.

8-4. Procedures.

a. Nuclear transportation regulations ensure safety by effective containment of the material; effective control of the radiation emitted from the package; preventing-criticality for fissile radioactive material; and adequate dissipation of any heat generated in a package. Primarily, safety in transport is accomplished by proper packaging of the radioactive material and by accurately communicating any associated hazards.

b. Hazard communication is achieved through correct marking, labeling, placarding, manifesting, and emergency response information.

8-5. Packaging.

a. In general, there are four types of packages used to transport radioactive material:

(1) Strong, tight containers (STC);

(2) Industrial packagings (IP-1, IP-2, and IP-3);

(3) Type A packages; and

(4) Type B packages.

b. The package required for a particular shipment of radioactive material is determined by the activity or quantity of the shipment. DOT categorizes quantities of radioactive material into five subtypes:

(1) EXCEPTED QUANTITIES which includes:

(a) Limited Quantities (173.421), must be in a STC;

(b) Instruments and Articles (173.424), must be in a STC;

(c) Manufactured Articles of U, DU, or Th (173.426), must be in a STC; and

(d) Empty Packages (173.428), must be in a STC.

(2) LSA QUANTITIES and SURFACE CONTAMINATED OBJECTS (173.427), in an industrial package, in a DOT Spec 7A Type A package, or in a STC;

(3) TYPE A QUANTITIES (þ A_1 or A_2 values in 173.435), must be in a Type A package;

(4) TYPE B QUANTITIES (þ A_1 or A_2 values in 173.435), must be in a Type B package; and

(5) HIGHWAY ROUTE CONTROLLED QUANTITIES (3000 X A_1 or A_2 values in 173.435, or exceed 27,000 Ci.), must be in a Type B package.

c. When preparing a shipment, a person should first determine the DOT subtype involved. Then, the person can determine the type of package required either by referring to the information and regulatory citations given above or by referring to column 5 of the Hazardous Materials Table (172.101).

d. Each shipper of a DOT Specification 7A package (a Type A package) must maintain on file for at least one year after the latest shipment, and shall provide to DOT on request, DOT package performance test records [49 CFR 173.415(a)].

e. Any shipper of a Type B package that has been approved by NRC in accordance with 10 CFR 71 shall be registered with the NRC as a party to the approval and the shipment must be made in compliance with the approval (49 CFR 173.471).

f. Anyone needing to ship radioactive material, but who has little experience doing so, should seek assistance from a qualified professional.

8-6. <u>Marking.</u>

a. Packages containing radioactive material must be marked according to 49 CFR 172.300. Proper marking includes:

(1) The proper shipping name and the identification number as shown in 49 CFR 172.101 for packages which are less than 110 gallons;

(2) If transferred to another carrier, the name and address of the shipper (consignor) or the receiver (consignee);

(3) The gross mass if greater than 110 pounds;

(4) “Type A” or “Type B” in ½ inch letters for these types of packages;

(5) “This End Up þ” for liquids;

(6) “USA” for international shipments; and

(7) “RQ” for reportable quantities (172.101, App. A).

(8) Shipments where the term “radioactive material” does not appear in the proper shipping name on the manifest and shipments not requiring a manifest must be marked

"Radioactive Material"

b. The markings must be durable, legible, in English, and printed on or firmly affixed to the package. The markings must be displayed on a background of a sharply contrasting color. Markings must be located away from other markings, such as advertising, that could substantially reduce the noticeability of the marking. Markings must not be covered or obscured by labels or attachments.

8-7. Labeling.

a. Packages containing radioactive material must be labeled according to 49 CFR 172.400. DOT specifies three categories of labels for packages containing radioactive material: Radioactive White-I, Radioactive Yellow-II, and Radioactive Yellow-III. The label required for a package depends on the radiation level at the package surface and at 1 meter from the package surface [the radiation level measured at 1 meter, in mrem/hr, and listed without units is also known as the transport index (TI)]. Each label must include the name of the radionuclide, the activity (in SI units followed by curie units in parentheses), and the TI (Radioactive Yellow-II and -III labels only). Proper labeling includes:

(1) Labels on two opposite sides excluding the bottom;

(2) Labels affixed near the markings (same side) and oriented in the same direction as the markings; and

(3) Label must be durable and able to withstand color change for 30 days.

b. Packages of Limited Quantities, Instruments and Articles, and Manufactured Articles of U, depleted uranium (DU), or Th are exempt from labeling requirements. EXCEPTED QUANTITIES prepared for shipment must have a notice (as written below) enclosed in or on the package, included with the packing list, or otherwise forwarded with the package. Limited Quantity packages and Manufactured Articles of U, DU, or Th packages must have the word "Radioactive" on the inner packaging. Empty packages must have an "Empty" label. LOW SPECIFIC ACTIVITY packages must have a "Radioactive-LSA" label.

c. Excepted quantities notice. The notice must include the name of the consignor or consignee and the statement "This package conforms to the conditions and limitations specified in 49 CFR 173.421 for excepted radioactive material, limited quantity, n.o.s., UN 2910; 49 CFR 173.422 for excepted radioactive material, instruments and articles, UN 2911; 49 CFR 173.424 for excepted radioactive material, articles manufactured from natural or depleted uranium or natural thorium UN 2909; or 40 CFR 173.427 for excepted radioactive material, empty packages, UN 2908" as appropriate.

8-8. Placarding.

a. A vehicle transporting a package labeled Radioactive Yellow-III or a vehicle transporting exclusively LOW SPECIFIC ACTIVITY packages and surface contaminated objects in accordance with 173.427(b)(3) must be placarded. The shipper must provide the carrier with all necessary placards. Proper placarding includes:

(1) Placards must be displayed on the front, rear and both sides of the vehicle;

(2) Placards must be durable, legible, and readily visible and must be at least three inches from other markings; and

(3) Placards must conform to the shape, size, color and design requirements specified 49 CFR 172.500.

b. Placarding is also required for vehicles transporting HIGHWAY ROUTE CONTROLLED QUANTITIES; however, the placard must be placed on a square background.

8-9. Manifesting.

a. Persons shipping other than EXCEPTED QUANTITIES of radioactive material must describe the material on a shipping paper as per 49 CFR 172.200.

b. A shipping paper must contain the following:

(1) A hazardous material entry which must consist of and/or appear as follows:

(a) Appear as the first entry on the shipping paper;

(b) Be designated by an “X” in the hazardous material column (“RQ” may be used in the case of hazardous substances); or

(c) Be highlighted or entered in a contrasting color.

(2) A shipping description which must include:

(a) The basic description - the proper shipping name, hazard class, and identification number (in that order);

(b) The total quantity;

(c) The name of each radionuclide (abbreviations are authorized);

(d) Physical and chemical form (if the material is not in special form);

(e) Activity per package measured in SI units followed by curie units in parentheses;

(f) Category of label applied (for example, Radioactive White-I);

(g) TI on Radioactive Yellow-II and Radioactive Yellow-III labels;

(h) For a shipment of fissile materials, see 172.203(d)(7);

(I) Type B package - Certificate of Approval from NRC or DOE, package identification;

(j) Import/export shipments - U.S. Certificate of Competent Authority number;

(k) “Highway Route Controlled Quantity” entered with the basic description for such shipments;

(l) “Limited Quantity” or “Ltd Qty” entered with the basic description for such shipments;

(m) An indication that the shipment is consigned as exclusive use for such shipments;

(n) LSA-I, LSA-II, LSA-III, SCO-I, or SCO-II for such shipments; and

(o) An emergency response telephone number (see paragraph 8-11c).

(3) Each entry must be separated from the next by a comma. The shipping paper must include a shipping certification statement worded exactly as described in 49 CFR 172.204(a). The certification must also include additional clauses for some materials and modes of transportation as described in 49 CFR 172.204. The shipping paper must be signed by the shipper.

(4) When transported by public highway, a shipping paper shall be within the driver's immediate reach while he/she is restrained by the lap belt and either readily visible to a person entering the driver's compartment (that is, NOT in the glove compartment) or in a holder which is mounted to the inside of the door on the driver's side of the vehicle.

8-10. Hazardous Waste Manifesting.

For a shipment of hazardous waste, which includes radioactive waste, a hazardous waste manifest must be prepared according to 40 CFR 262. The RCRA definition of hazardous waste includes mixed waste but not radioactive waste (see Chapter 9 for a definition of mixed waste).

8-11. Emergency Response Information.

a. Persons shipping other than EXCEPTED QUANTITIES of radioactive material must supply emergency response information as required in 49 CFR 172.600. This emergency information must contain:

(1) The basic description as required by 49 CFR 172.202;

(2) The immediate health hazards;

(3) The risk of fire or explosion;

(4) Precautions to be taken in the event of an accident;

(5) Methods for handling fires;

(6) Methods for handling spills or leaks; and

(7) First aid measures.

b. The information must be in English and be located away from the package containing the radioactive material. The information required must be presented on a shipping paper, in a separate document (for example, a material safety data sheet), or in a guidance document [40 CFR 172.602(b)]. The information must be accessible to persons entering the vehicle.

c. A 24-hour emergency response telephone number must be on the shipping paper. The emergency response number must be manned by a person who is either knowledgeable of the radioactive material and knows the proper emergency response procedures or has immediate access to someone who does. The emergency number must be for either the person making the radioactive material shipment or for a company willing to accept the responsibility for emergency response. The person making the shipment must ensure that the company is capable of performing the emergency response necessary.

8-12. Hazmat Employee Training.

a. A hazmat employer is defined by DOT as a person who uses one or more of its employees in connection with, among other things, transporting hazardous materials in commerce. A hazmat employee directly affects hazardous materials transportation safety. It is a hazmat employer's responsibility to ensure that each of its hazmat employees receives training such that hazmat employees can recognize and identify hazardous materials, know how to respond in an emergency situation, know self-protection measures, and know accident prevention methods (49 CFR 172.700).

b. Hazmat employees shall receive the training at least once every two years. Training provided by employers to comply with OSHA regulations (29 CFR 1910.120) or EPA regulations (40 CFR 311.1) may be used to satisfy DOT’s hazmat employee training requirements if the topics specified in the preceding paragraph are covered.

c. Subpart I, “Radiation protection program.” of 49 CFR 172 requires that a hazmat employee’s annual effective dose equivalent of occupational radiation exposure not exceed 1.25 rem per three months or five rem per 12 months (0.125 rem per three months or 0.5 rem per 12 months for workers under the age of eighteen).

8-13. Exceptions.

Exceptions exist for nearly all DOT regulations. These exceptions are listed in Title 49 near each applicable part. One major exception of importance is that the International Air Transport Association (IATA) Dangerous Goods Regulations may be used in place of Title 49 for any shipment where at least one leg of the shipment will be by air. IATA is similar to, but much simpler than, Title 49.

Chapter 9. Waste management.

Radioactive waste management is an important part of a Radiation Protection Program. There are few options for disposal of radioactive waste and all are costly. A well thought out waste management program will make radiation protection simpler and less expensive.

9-1. Regulation of Radioactive Wastes.

a. Oversight Agencies.

(1) The NRC regulates source, byproduct and special nuclear material only. Agreement States may include NORM and NARM within their jurisdiction. Congress mandated that states dispose of the radioactive waste generated within their borders. The states formed compacts to allow construction of one facility for the disposal of waste from all states within the compact. Compact commissions regulate the disposal of waste within their compact states and control the import and export of radioactive waste to and from their states.

(2) The EPA regulates radioactive material at CERCLA sites, in air emissions, and in drinking water. Legislation is underway to allow EPA to regulate allowable radiation exposure to the public from any man-made source.

(3) Table 9-1 is a listing of major laws and regulations pertinent to low level radioactive waste (LLRW) and mixed waste disposal, site remediation, and operational practices. The following paragraphs describe the various agencies propounding those regulations. This chapter is not an exhaustive description or listing of all applicable laws and regulations. Identification of applicable laws and regulations is a site-specific determination made only after full consultation with a regulatory specialist and Office of Counsel.

b. Department of Army.

(1) The U.S. Army Industrial Operations Command (AIOC), AMSIO-DMW, Rock Island, IL 61299-6000, has been appointed as the executing agent for disposal of DOD radioactive waste. The executing agent is responsible for inventorying and reporting all DOD waste disposal. The executing agent also serves as the POC for the disposal compacts and operates two DOD

TABLE 9-1
Low Level Radioactive Waste Laws and Regulations

DOT	EPA	NRC	OSHA	DOE	DOD
Regulates interstate transportation of DOT defined radioactive materials (>2000 pCi/g). Title 49	Regulates mixed waste, air and water emissions. Title 40	Regulates source, byproduct, and special nuclear material; also applies DOT regulations to intrastate shipments of radioactive material. Title 10	Regulates worker health and safety. Still applies old 10 CFR 20 regulations. Title 29	Regulates radioactive material on DOE sites and nuclear weapons materials. Title 10	Responsible for DOD licensed radioactive material and ARA authorized materials. AR 385-11

storage facilities for radioactive waste that cannot be disposed due to compact status.

(2) USACE is responsible for remediation of radioactive wastes at formerly used defense sites (FUDS), and at the discretion of the installation commander, for remediation of radioactive and mixed wastes on active and base realignment and closure (BRAC) listed bases. USACE is also involved with LLRW disposal during other DOD installation environmental restoration actions. USACE disposal of DOD LLRW waste must be coordinated through the HTRW-CX. The action will then be coordinated with the DOD executing agent for low-level radioactive waste disposal.

(3) Non-DOD (for example, RCRA Corrective Action) LLRW waste disposal will be coordinated with the HTRW-CX.

9-2. Low Level Radioactive Waste (LLRW).

a. LLRW is defined as all radioactive waste that is not high level waste or uranium or thorium mill tailings. This definition was enacted for purposes of determining methods of disposal of LLRW and high level radioactive wastes. Most radioactive waste USACE may manage is LLRW. LLRW should not be construed to present a low hazard. The hazards of radioactive wastes are determined by the type and quantity of radiation emitted.

b. Mixed Waste.

Mixed waste is defined as waste composed of NRC regulated radioactive materials mixed with RCRA (Resource Conservation and Recovery Act) listed hazardous wastes, and/or RCRA characteristic hazardous waste. The radioactive components of mixed waste regulated by the NRC are source, byproduct or special nuclear material, and the hazardous component of mixed waste is regulated by EPA. A hazardous waste is defined in 40 CFR 261 as a solid waste which exhibits a hazardous characteristic, is "listed" in the regulations, or is a mixture of hazardous and solid wastes.

c. Radioactive material which is not source, byproduct or special nuclear material is not regulated by the NRC, but may be regulated by Agreement States, depending on the state laws. Hazardous wastes that are not RCRA listed or characteristic hazardous wastes may be regulated by the state as a hazardous waste under state hazardous waste management laws. The state does not need to be RCRA-authorized to establish this authority. When non-NRC regulated radioactive material is mixed with RCRA hazardous waste, or with state listed hazardous waste, or when NRC regulated radioactive material is mixed with state listed hazardous waste, the waste is considered to be combined waste, also called co-mingled waste.

d. The distinction between mixed and combined or co-mingled waste is important because the disposal options differ. There are a number of disposal options for combined or co-mingled waste, but only a few options for mixed waste.

e. Agreement States are listed in Table 4-2. LLRW compacts are shown on the map located in Appendix H.

f. Mixed Waste Amendment. The mixed waste amendment is found in Section 105 of the Federal Facilities Compliance Act of 1992. The amendment created a new mixed waste provision within RCRA. The amendment required DOE to submit a plan with schedules for all applicable permit applications, construction activities and processing of mixed waste at each of the DOE sites. Any USACE activity doing work for DOE should verify if a plan exists for the site and if there are any compliance schedules or permits in place. Examination of compliance schedules should include evaluating the hazardous portion regulated under RCRA. The RCRA compliance schedules may contain critical time-lines for USACE to meet in order to stay in compliance. The mixed waste amendment also required EPA or EPA authorized states to receive a copy of the mixed waste management plan for review and approval.

9-3. Elements of a Waste Management Program.

There are five elements of a radioactive waste management program. These elements are:

a. Material tracking;

b. Waste minimization;

c. Waste recycling;

d. Waste storage; and

e. Waste disposal.

9-4. Material Tracking.

Any project involving radioactive material will have a radioactive material tracking program in effect. This program will document the arrival on site of the radioactive material, the package receipt procedures, an active inventory of all materials and their locations at all times, all radioactive waste generated, and the final disposal of the radioactive material. Radioactive material will be tracked using the Record of Radioactive Material form (ENG 3309-R). On HTRW sites where there is radioactive contamination, the radioactive material will be entered into a tracking program as the contamination is containerized, or remediated. Each container will be labeled as described in Chapter 8, and tracked, from inception until final disposal at the disposal site.

9-5. Waste Minimization.

The most effective method of dealing with radioactive waste is to not generate it. This is often the case when using sealed sources. When working with unsealed sources or on HTRW sites this is usually not possible. Radioactive waste disposal costs are based on the cubic foot of waste at shallow land burial sites and by the gallon at incinerators, so there is a financial incentive to minimize the amount of waste produced and the volume of waste disposed. Where radioactive waste is generated or packaged, waste minimization techniques should be used. These techniques include avoiding equipment contamination, limiting the spread of contamination, decontamination of items where it is cost effective, efficient packing of bulky items and compaction or supercompaction where possible.

9-6. Waste Recycling.

A number of companies will recycle certain radioactive and mixed wastes. Sealed sources are often in demand by companies and universities. Radioactively contaminated metals can be smelted and cast as parts for disposal containers for other radioactive wastes. If a project involves recyclable radioactive wastes, contact the HTRW-CX for a POC at the recycling companies.

9-7. Waste Storage.

Due to the status of some low level radioactive waste state compacts, there may be no disposal option for some radioactive wastes. Storage on site in most cases requires NRC or Agreement State licensing of the site and is generally not recommended. If the waste is a mixed waste, the RCRA time limit for storage on-site without a part B permit may be in effect. The US Army has contracted two facilities for long term storage of radioactive wastes. Neither facility has a Part B permit, so neither can store mixed, combined or co-mingled wastes. If long term storage is needed, contact the HTRW CX to arrange for use of the US Army facilities.

9-8. Waste Disposal.

a. Radioactive wastes can be disposed of in the following ways.

(1) An NRC licensed facility is allowed to release limited concentrations of radionuclides into the air or water. Small quantities can be disposed of in a sanitary sewer. Concentrations that can be disposed of by these methods are listed in Appendix B of 10 CFR 20.

(2) 10 CFR 20 also allows disposal of, and incineration of liquid scintillation fluids or animal tissue containing tritium or carbon-14 at concentrations of 0.05 microcurie per gram or less without regard to the radioactivity of the medium. Many liquid scintillation cocktails contain toluene or xylene which are RCRA hazardous wastes. The liquid scintillation cocktails that contain these, or other hazardous wastes, must still be disposed of as hazardous wastes.

(3) NRC licensed radioactive material which is considered waste and cannot be disposed of by the above methods, must be disposed of at a licensed LLRW disposal facility.

b. A classification system has been developed to segregate LLRW by hazard for disposal at near surface disposal sites. The hazard is based on the longevity and the radiation emitted. There are certain requirements to be met for all classes of LLRW, intended to facilitate handling and provide protection to the site personnel, the nearby public, and potential intruders into the disposal facility.

LLRW is classified as to the degree of rigor required for the disposal method.

(1) The acceptable physical characteristics of LLRW and the containers it is disposed in are determined by conditions on the disposal site's radioactive material license. Exemptions may be applied for and are granted if there is no increase in the hazards or risk to the public and environment.

(2) Some LLRW restrictions applied at disposal facilities include the following:

(a) Waste may not be packaged in cardboard or fiberboard boxes.

(b) Liquid LLRW must be solidified or packaged in sufficient absorbent material. Solid LLRW containing liquid shall contain as little free noncorrosive liquid as possible, not to exceed one percent by volume.

(c) LLRW must not be capable of detonation, explosion, or any other violent decomposition under ordinary disposal unit conditions.

(d) LLRW shall not contain or generate quantities of toxic fumes or gases during handling, transport, or disposal.

(e) LLRW must not be pyrophoric; waste containing pyrophoric materials shall be stabilized or treated to become a nonflammable waste.

(f) Gaseous LLRW must be packaged at less than 1.5 atmospheres pressure at 20 degrees Celsius and each container will not contain more than 100 Ci total.

(g) LLRW containing hazardous, biologic, pathogenic or infectious material must be treated to reduce the potential hazard from the non-radiological materials.

(h) LLRW must possess structural stability to avoid degrading the containment and the site. It will generally maintain its physical dimensions and form under the expected disposal conditions. Conditions to consider in assessing structural stability include weight of overburden, presence of moisture, microbial activity, radiation effects, and chemical changes. The waste form itself may provide structural stability before or after processing; or the waste may be placed in structurally stable containers or structures for disposal. Generally, only those stabilization media which have been evaluated according to the stability guidance requirements of the NRC's Low Level Licensing Branch, Technical Position on Waste Form, are considered acceptable media. Liquid LLRW must be converted to a form containing as little free-standing and noncorrosive liquid as reasonably achievable. The volumetric content of the LLRW part of liquid or solid waste will not exceed 1 percent of a single container or 0.5 percent of the volume of waste processed to a stable form. Void spaces within the waste and between the waste and its package will be reduced as much as reasonably possible.

c. Class A LLRW.

(1) Class A LLRW is waste that does not contain sufficient amounts of radionuclides to be of concern with respect to migration, long term active site maintenance, and potential exposure to intruders. Class A LLRW tends to be stable. Class A LLRW is usually segregated from other waste classes at the disposal site. Class A LLRW must meet the minimum handling characteristics required and described above.

(2) Class A LLRW has concentrations less than columns 1 and 4 as shown in Table 9-2, Concentration/ Activity Levels for LLRW Classification.

d. Class B.

(1) Class B LLRW must meet more rigorous standards for stability than Class A. Class B LLRW is more highly radioactive than Class A.

(2)Class B LLRW has concentrations greater than column 1 and less than column 2 as shown in Table 9-2.

e. Class C.

(1) Class C LLRW must meet the most rigorous standards on waste form stability and additional measures at the disposal facility to protect against inadvertent intrusion.

(2) Class C LLRW has concentrations greater than column 2 and less than column 3, and less than column 5 as shown in Table 9-2.

f. Greater than Class C.

(1) Waste classified as greater than Class C is not suitable for near surface disposal.

(2) Greater than Class C LLRW has concentrations greater than column 5.

9-9. Radionuclide Concentrations.

Concentrations may be measured directly or calculated if there is reasonable assurance of correlation to direct measurements. Indirect methods of concentration determination include inference of one nuclide concentration from that of another which is directly measured, and material inventory records. Concentrations may be averaged by weight or by volume.

Table 9-2
Concentration/activity levels for LLRW Classification

Concentration Nuclide	Col. 1 Ci/m^3	Col. 2 Ci/m^3	Col. 3 Ci/m^3	Col.4 Ci/m^3	Col. 5 Ci/m^3
C-14				0.8	8
C-14 activated metal				8	80
Ni-59 activated metal				22	220
Nb-94 activated metal				0.02	0.2
Tc-99				0.3	3
I-129				0	8
TRU with halflife > 5 yrs.				10 nCi/g	100 nCi/g
Pu-241				350 nCi/g	3500 nCi/g
Cm-242				2,000 nCi/g	20,000 nCi/g
all halflives < 5 yrs.	700				
H-3	40				
Co-60	700				
Ni-63	3.5	70	700		
Ni-63 activated metal	35	700	7000		
Sr-90	0.04	150	7000		
Cs-137	1	44	4600		

Mixtures are determined by the sum of the fractions rule.

Chapter 10. Laser Safety.

As stated in Chapter 2, any Command whose personnel are occupationally exposed to class IIIb or class IV lasers shall have a Laser Safety Officer (LSO). The LSO shall ensure that personnel exposure to laser radiation is kept within guidelines listed in ANSI Z136.1 and ANSI Z136.3, and that work with lasers is accomplished in accordance with OSHA regulations as stated in 29 CFR 1926.54, and USACE guidance in EM 385-1-1. This shall be accomplished by establishing and ensuring compliance with a Laser Protection Program.

10-1. Classifications of lasers.

a. Lasers are classified by their hazard capabilities. The ANSI Z136.1 standard accurately defines the classifications of lasers depending on the power output and light wavelength, but in general the classifications are as follows:

(1) Class I - Cannot produce hazardous radiation. These devices may contain an embedded class IIIb or class IV laser.

(2) Class II - Continuous intrabeam exposure may damage the eye. Momentary intrabeam exposure (<0.25 second) is not damaging to the eye.

(3) Class III - Can damage the eye during momentary intrabeam exposure.

(a) - Class IIIA: intermediate power lasers (1-5 mW). Only hazardous for intrabeam viewing.

(b) - Class IIIB: moderate power lasers (5-500 mW). In general Class IIIB lasers will not be a fire hazard, nor are they generally capable of producing a hazardous diffuse reflection.

(4) Class IV - May damage the skin as well as the eye during momentary intrabeam exposure or exposure to diffuse reflection. These lasers may be fire hazards and may produce laser generated air contaminants(ozone) and plasma radiation.

10-2 Safety Features and Labeling Requirements.

The Department of Health and Human Services in 21 CFR 1000-1050, the ANSI standards, and USACE EM 385-1-1 require that certain engineered safety features and labeling be used with the different classes of lasers. Table 10-1 cross-references the safety features and label requirements for each class of lasers. Examples of laser labels and area postings are included in Appendix F.

Lasers may have additional safety features or labeling requirements. Check the manufacturer's manual for additional labeling requirements.

TABLE 10-1
Laser Safety Features and Labeling Requirements

Safety Feature	Class			
Safety Features	I	II	III	IV
Protective Housing	X	X	X	X
Safety Interlock	X	X	X	X
Remote Connector			X	X
Key Control			X	X
Emission Indicator		X	X	X
Beam attenuator		X	X	X
Labels	I	II	III	IV
Certification and Manufacturer	X	X	X	X
Class Designation and Warning Logotype		X	X	X
Aperture Label		X	X	X
Radiation Output		X	X	X
Non-interlocked Protective Housing		X	X	X

10-3. Laser Protection Program.

A Laser Protection Program, as required for Commands where personnel may be exposed to class IIIa, class IIIb or class IV laser radiation should consist of the following elements:

a. A list of personnel responsibilities and qualifications,

b. A list of training requirements for operators and bystanders,

c. A description of the types and hazard potentials for the types of lasers used in the Command,

d. A description of laser safety measures used in the Command,

e. A compendium of Standing Operating Procedures for the lasers used within the Command,

f. An emergency response plan.

10-4. OSHA standards.

OSHA 29 CFR 1926.54 addresses worker exposure to non-ionizing radiation. OSHA requires that:

a. Only qualified and trained personnel work with laser equipment,

b. Proof of qualification shall be carried by the operator,

c. If the potential for exposure to direct or reflected laser light above the exposure limit exists, then workers will be furnished with acceptable eye protection,

d. Laser work areas must be properly posted,

e. Beam shutters and caps must be utilized,

f. Unattended lasers shall be shut off,

g. Only mechanical or electrical means will be used for beam alignment; beam alignment will not be made by eye.

h. The beam shall not be directed at employees,

i. Lasers shall not be used in the rain or in foggy conditions if possible,

j. Each laser shall be labeled to indicate its maximum output,

k. Lasers shall be used above the heads of personnel when possible; and

l. Employees shall not be exposed to light intensities above the exposure limits.

10-5. USACE Standards.

The Army and USACE have adopted the current American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs) as the limits for employee exposure to lasers. The ACGIH TLVs are essentially the same as the ANSI Z136.1 standards. TLVs are dependent upon the wavelength of the light and the duration of exposure. Consult with the Command Laser Protection Officer to determine the TLV for each laser used within the Command.

10-6. Protective eyewear.

Protective goggles may be required when using some lasers. The protection factor of goggles depends on the wavelength of the laser light and the amount of energy the laser can deposit at the site of exposure. The exact optical density required for any specific laser use scenario may be calculated using equations in ANSI Z136.1, or Table 10-2 may be used. Goggles must have a label listing the laser wavelengths for which they provide protection, their optical density at those wavelengths, and the amount of visible light that the goggles transmit. The LSO should verify the optical density calculation.

Table 10-2
Optical Density Requirements

Intensity, Continuous Wave Max. Power Density (watts/cm^2)	Optical Density	Attenuation Factor
0.01	5	10,000
0.1	6	100,000
1.0	7	1,000,000
10.0	8	10,000,000

Chapter 11. Radio Frequency (RF) and Microwave Safety.

11-1. DA Limits.

The DOD and DA, in DODI 6055.11, have adopted the IEEE C95.1-1991, IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency (RF) Electromagnetic Fields, 3 kHz to 300 GHz maximum permissible exposure to RF levels. The guiding principle is that no practice shall be adopted or operation conducted involving planned exposure to RF levels in excess of the applicable Permissible Exposure Limit (PEL).

11-2. USACE Limits.

USACE, in compliance with DODI 6055.11, has adopted the IEEE maximum permissible exposure levels for a controlled area. These PELs are presented in Table 11-1. Maximum PEL's for uncontrolled environments are presented in Table 11-2.

11-3. OSHA Regulations.

OSHA set a radiation protection guide for non-ionizing radiation, including electromagnetic radiation. The radiation protection guide is a level of radiation which should not be exceeded without careful consideration of the reasons for doing so. The OSHA radiation protection guide is 10 mW/cm^2 (milliwatts/square centimeter) power density averaged over six minutes, or 1 $mW\text{-}hr/cm^2$ energy density averaged over 6 minutes.
OSHA also requires that a standard radio frequency radiation hazard sign be used to notify employees of possible exposure.

11-4. General Guidance.

a. As with all radiation, only personnel who have been trained in the safe use of the equipment should work with the equipment. Similarly, only trained personnel, using calibrated instrumentation, should be used to assess, survey or evaluate non-ionizing radiation fields, personnel exposures and control measure determinations.

b. NOTE: Non-ionizing radiation TLVs may not protect against electromagnetic interference with cardiac pacemakers. Persons wearing pacemakers should check the manufacturer's literature to ensure TLVs are adequate to avoid interference.

c. The basic dosimetric parameter for RF exposure is the Specific Absorption Rate (SAR). The SAR of 0.4 watts per kilogram has been set as the maximum exposure for humans. This is a factor of 10 below the level of exposure determined to potentially cause deleterious effects in humans.

The PELs are listed in terms of measurable field parameters that act as a convenient correlation to the SAR.

d. There are exceptions to the listed PELs for certain exposures and situations. These are listed in DODI 6055.

11-5. Warning Signs.

a. RF warning signs are required to be posted at all access points to areas where levels exceed the PELs. Posting should be determined and maintained by the Safety and Occupational Health Office (SOHO).

b. Where 10 times the PELs are exceeded, other warning devices, such as flashing lights, audible signals, barriers or interlocks should be used.

c. RF protective clothing shall not be used as a routine method of protecting personnel from RF levels that exceed the PELs.

11-6. RF Safety Training.

USACE personnel routinely working with equipment that emits RF levels that may exceed the PELs shall receive training from the SOHO, addressing:

a. the potential hazards of RF,

b. procedures and restrictions to control RF exposures, and

c. their responsibility to limit their RF exposure.

Timely refresher training in RF safety shall be incorporated into other periodic safety training programs.

Table 11-1
Radio Frequency/Microwave Permissible Exposure Limits for Controlled Environments

Part A-Electromagnetic Fields (f = frequency in MHZ)				
Frequency	Power Density, S (mW/cm^2)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)	Averaging Time E^2, H^2 or S (minutes)
30 kHz-100 kHz	102, 106	614	163	6
100 kHz-3 MHZ	102, 104/f^2	614	16.3/f	6
3 MHZ-30 MHZ	900/f^2, 104/f^2	1842/f	16.3/f	6
30 MHZ-100 MHZ	1.0, 104/f^2	61.4	16.3/f	6
100 MHZ-300 MHZ	1	61.4	0.163	6
300 MHZ-3 GHz	f/300			6
3 GHz-15 GHz	10			6
15 GHz-300 GHz	10			616,000/$f^{1.2}$

The exposure values in terms of electric and magnetic field strengths are the values obtained by spatially averaging values over an area equivalent to the vertical cross-section of the human body (projected area).

Part B-Induced and Contact Radio Frequency Currents* Maximum Current (mA)			
Frequency	Through Both Feet	Through Each Foot	Contact
30 kHz-100 kHz	2000f	1000f	1000f
100 kHz-100 MHZ	200	100	100

* It should be noted that the current limits given above may not adequately protect against startle reactions and burns caused by transient discharges when contacting an energized object.

Part C-Pulsed RF Fields		
Frequency	Peak Electric Field (kV/m)	Peak Power Density/ Pulse for Pulse Durations < 100 msec. (mW/cm^2)
100 kHz - 300 GHz	100	(PEL)(T_{avg})/5 (pulse width)

Part D-Partial Body Exposures		
Frequency	Peak Value of Mean Squared Field (V^2/m^2 or A^2/m^2)	Equivalent Power Density (mW/cm^2)
100 kHz - 300 MHZ	<20*E^2 or <20*H^2	
300 MHZ - 6 GHz	<20*E^2 or <20*H^2	<20
6 GHZ - 96 GHZ	<20*E^2 or <20*H^2	<20(f/6000)0.25
96 GHz - 300 GHZ	<20*E^2 or <20*H^2	40

V^2/m^2: volts squared / meter squared = E (electric field) squared.

A^2/m^2: amps squared / meter squared = H (magnetic field) squared.

T_{avg}: average pulse time.

Table 11-2
Radio Frequency/Microwave Permissible Exposure Limits for Uncontrolled Environments

Part A-Electromagnetic Fields (f = frequency in MHZ)				
Frequency	Power Density, S (mW/cm^2)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)	Averaging Time E^2, H^2 or S (minutes)
30 kHz-100 kHz	102, 106	614	163	6, 6
100 kHz-134 kHz	102, $104/f^2$	614	16.3/f	6, 6
134 kHz - 3 MHZ	$180/f^2$, $104/f^2$	823.8/f	16.3/f	f2/0.3, 6
3 MHZ-30 MHZ	$180/f^2$, $104/f^2$	823.8/f	16.3/f	30, 6
30 MHZ-100 MHZ	0.2, 9.4X105/ $f^{3.36}$	27.5	158.3/ $f^{1.1668}$	30, $0.0636f^{1337}$
100 MHZ-300 MHZ	0.2	27.5	0.0729	30, 30
300 MHZ-3 GHZ	-		f/1500	30, -
3 GHZ-15 GHZ	-		f/1500	90,000/f
15 GHZ-300 GHZ	-		10	$616,000/f^{1.2}$
The exposure values in terms of electric and magnetic field strengths are the values obtained by spatially averaging values over an area equivalent to the vertical cross-section of the human body (projected area).				

Part B-Induced and Contact Radio Frequency Currents* Maximum Current (mA)			
Frequency	Through Both Feet	Through Each Foot	Contact
30 kHz-100 kHz	900f	450f	450f
100 kHz-100 MHZ	90	45	45

* It should be noted that the current limits given above may not adequately protect against startle reactions and burns caused by transient discharges when contacting an energized object

Part C-Pulsed RF Fields		
Frequency	Peak Electric Field (kV/m)	Peak Power Density/ Pulse for Pulse Durations < 100 msec. (mW/cm^2)
100 kHz - 300 GHZ	100	PEL)(T_{avg})/5 (pulse width)

Part D-Partial Body Exposures		
Frequency	Peak Value of Mean Squared Field (V^2/m^2 or A^2/m^2)	Equivalent Power Density (mW/cm^2)
100 kHz - 300 MHZ	$<20*E^2$ or $<20*H^2$	
300 MHZ - 6 GHZ	$<20*E^2$ or $<20*H^2$	<4
6 GHz - 96 GHZ	$<20*E^2$ or $<20*H^2$	f/1500
96 GHz - 300 GHZ	$<20*E^2$ or $<20*H^2$	20

V^2/m^2: volts squared / meter squared = E (electric field) squared.

A^2/m^2: amps squared / meter squared = H (magnetic field) squared.

T_{avg}: average pulse time.